Does Participating in Global Value Chains Lead to Export Quality Upgrading?*

Lin Shi†

December 11, 2024

Click Here for Latest Version

Abstract

A country's prospect of structural transformation relies on both a progressive diversification of the production base and an upgrade of production quality. These aspects of sustainable development are crucial in the global value chain (GVC) context, though empirical literature explicitly assessing the impact of GVC on quality upgrading remains scarce. In this paper, I examine the causal effect of GVC participation on export quality upgrading, explore the heterogeneous impact among countries and industries, and construct a country-industry upstreamness measure to examine the various effects along the positions of the value chains. I find consistent evidence that increasing GVC participation has a positive and statistically significant effect on export quality. An increase in domestic value-added embodied in foreign exports as a share of domestic gross exports (forward GVC participation) has a pronounced and robust effect on export quality upgrading. However, the effect of foreign value-added in an industry's exports as a share of gross exports (backward GVC participation) is largely muted. The impact of increasing forward GVC participation on export quality is positive and significant among both advanced and developing countries, countries which have transitioned to a higher income status, and East Asia and Pacific countries. In terms of sectoral heterogeneities, three patterns can be observed. First, the impact is predominantly driven by manufacturing sectors. Second, increasing GVC participation in sectors with lower research and development intensities is associated with a decrease in sectoral export quality. Third, an increasing share of sectoral differentiated products is a positive and significant determinant of export quality upgrading. Last, I find that country-industry pairs in extremely upstream positions can improve export quality by increasing backward GVC participation, while those that are closer to final uses can benefit from strengthening forward GVC participation.

Keywords: Global value chains, input-output tables, quality upgrading, R&D, structural transformation

JEL codes: D57, F12, F14, F15, F63

*I express my utmost gratitude and appreciation to my committee members Professor Robert Blecker, Professor Robert Feinberg, and Professor Kara Reynolds for their continued support and extremely helpful comments and discussions as this paper takes shape. I am grateful for the feedback and suggestions received at the Southern Economic Association Conference, Global Trade Analysis Project Conference, Chinese Economics Society Annual Conference, and the American University Robyn Rafferty Mathias Student Research Conference. All potential errors are my own.

†Ph.D. Candidate in Economics and Adjunct Instructor at American University. 4400 Massachusetts Avenue NW, Washington D.C., 20016. ls6953a@american.edu

1 Introduction

A global value chain (GVC) is defined as international production fragmentation such that intermediate goods and services, rather than final goods, are exchanged across borders multiple times in the production process. Over the past several decades, the world has seen an upward trend of GVC trade as a percentage of world trade. As shown in Figure 1, the World Development Report (WBG, 2020) estimates that GVC trade increased from 37 percent in 1970 to 52 percent in 2008, followed by a sizable decline to 47 percent in 2015. The fluctuating trend of GVC trade reflects the integration and decoupling trade patterns in an interconnected global economy.

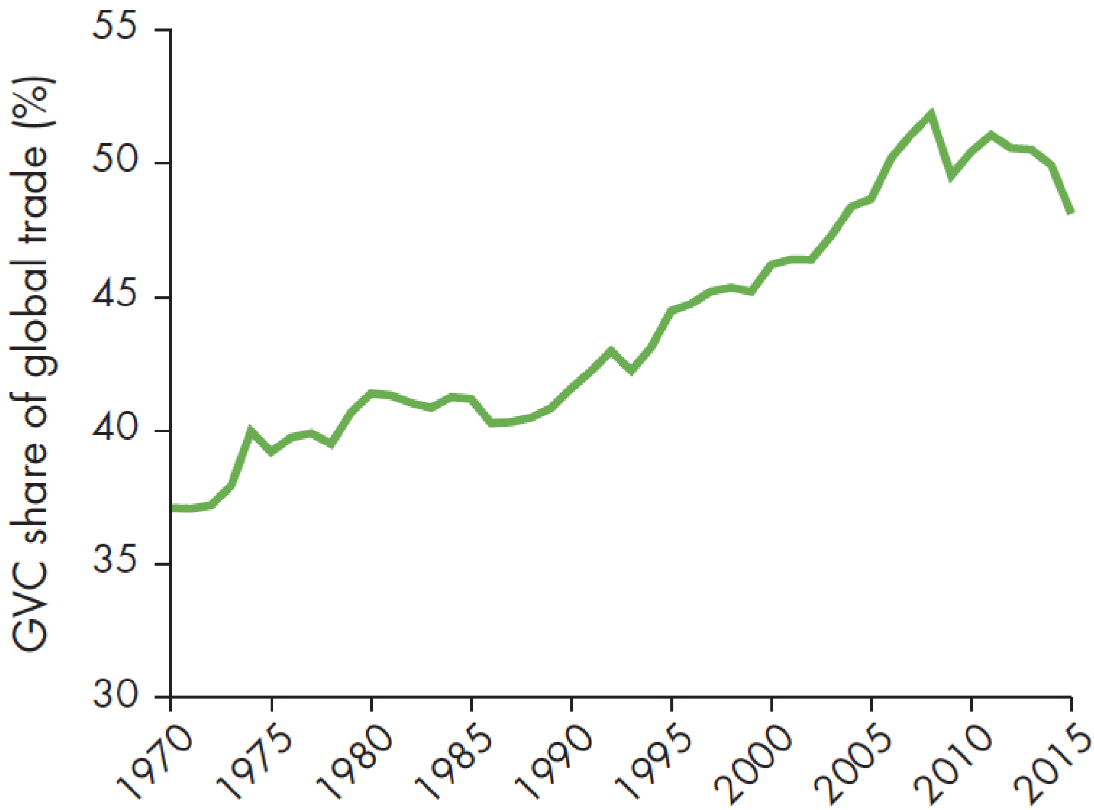


Figure 1. GVC Trade as a Share of Global Trade, 1970-2015

Source: Reproduced from Figure 1.2 in the World Development Report (2020). Originally produced by the WDR (2020) Team, using data from the Eora26 dataset, based on the methodology of Borin and Mancini (2019) and Johnson and Noguera (2017).

GVC trade is distinguished from traditional trade in terms of conceptual differences. While traditional trade concerns "trade in goods", GVC trade represents a conceptual shift towards "trade in tasks". Compared to customs data which suffers from double-counting, GVC data more accurately traces value-added trade flows across countries and sectors, therefore is a better reflection of a country-sector's contribution in the global production process.

From a policy perspective, GVC trade also has unique implications for countries' prospects of structural transformation, with dynamic gains from trade compared to static gains from trade in final goods. UNCTAD (2016) defines structural transformation as a continuous process which involves: (1) a progressive diversification of the production base, and (2) an upgrade towards increasingly sophisticated goods and production methods, caused by technological change. Structural transformation is crucial to meaningful, sustained economic development. Commonly brought forth by major socioeconomic changes, it can drastically impact the structure of an economy by affecting aggregate economic growth. In addition, it may lead to a redistribution of income or wealth through its impact on the factor shares of production. Moreover, structural change may interact with business cycles and international trade, potentially stabilizing previously vulnerable economies and facilitating swift recoveries in turbulent market conditions. For developing countries, structural transformation signifies the ability to mobilize their productive resources from low-productivity to high-performing sectors.

In traditional trade theory, a country's specialization and trade pattern is based on conditions such as technology, relative abundance of factors of production, or factor mobility/immobility. In these models, a country exports the good in which it has a comparative advantage. The theoretical frameworks do not take into account the dynamic changes in trade patterns due to factors such as international or regional knowledge spillover, learning-by-doing, or technological leapfrogging. In contrast, GVC trade exhibits dynamic gains from trade through at least three potential channels. First, GVC trade indicates a finer division of labor and a more efficient allocation of resources, lowering production costs through specialization. As modeled in Feenstra and Hanson (1997), developed economies offshore relatively unskilled labor-intensive tasks to foreign economies to take advantage of lower wages, which increases the relative demand for skilled labor in emerging markets and developing economies (EMDEs) that engage in outsourcing. Second, GVC trade can potentially improve countries and sectors' productive capabilities and facilitate knowledge transmission through both forward and backward GVC participation. Forward GVC participation, which represents the seller's perspective, is defined as domestic value-added embodied in foreign exports as a percentage of gross exports. Backward GVC participation, which represents the buyer's perspective, is defined as foreign value-added in an industry's exports as a share of total gross exports. Forward GVC linkages can potentially lead to export quality upgrading through learning-by-doing and the spillover effects of knowledge transmission at the industry, regional, or international level. Backward GVC linkages potentially facilitate export quality upgrading from upstream to downstream sectors as the imported intermediates can embody higher-technological contents to be built upon, and the downstream producers may receive training and guidance to adhere to the specification requirements of the upstream sectors. Third, participating in GVC trade in an interconnected world diversifies trading partners in an increasingly fragmented global economy, therefore facilitating countries to engage in risk-sharing, maintain multilateral trading partnerships, and dive into frontier, strategic sectors when facing economic and geopolitical shocks.

These channels suggest that comparative advantage in the context of GVC trade is dynamic: Sustainable, meaningful economic development requires countries to shift production and trade towards goods and tasks without a pre-existing comparative advantage. China's rise in the solar energy sector offers a concrete example. Despite having negligible prior experience in photovoltaic (PV, a.k.a. solar panels) technologies, China began to address government policy support for PV panel manufacturing in its Sixth Five-Year Plan (1981-1985) and included it in every Five-Year Plan since then. According to a research at University of California San Diego[1], since the 1990s, China has implemented a series of policies, including developing and promoting solar water heaters nationwide, operating its first domestic PV cell production line in 2002, exporting its PV cells to Europe (especially Germany) since 2004, and subsidizing the heavily export-dependent PV industry after the 2008 global financial crisis. In recent years, China has displayed competitiveness in the solar energy sector. Bradsher (2024) at the *New York Times* reported[2] that China has considerable cost advantage in producing solar panels: Chinese companies can produce solar panels for 16 to 18.9 cents per watt of generating capacity, compared to 24.3 to 30 cents per watt for European companies and about 28 cents for American companies.

Motivated by the potential impact of GVC trade on structural transformation through various channels, I examine whether participating in GVCs leads to export quality upgrading. Marcato and Baltar (2020) as well as Humphrey and Schmitz

[1] https://chinafocus.ucsd.edu/2021/02/16/solar-energy-in-china-the-past-present-and-future/
[2] https://www.nytimes.com/2024/03/07/business/china-solar-energy-exports.html

(2002) show that there are various definitions and measures in quantifying "economic upgrading" in the GVC context. Humphrey and Schmitz (2002) identify four types of upgrading in GVCs: (1) process upgrading; (2) product upgrading; (3) functional upgrading; and (4) inter-sectoral upgrading. In this article, I focus on product upgrading, which is the ability to move into more sophisticated product lines (which can be estimated in terms of higher unit values). Using the product-level export quality data from the *IMF Export Diversification and Quality Databases*, I create crosswalks between the SITC Rev.1 product classification and the ISIC Rev.4 industry classification to construct the average export quality measure at the industry granularity, consistent with that of the GVC indicators. For the scope of this paper, I define export quality upgrading as an increase in the sectoral value of export quality.

The purpose of this paper is three-fold. First, by combining the *OECD Trade in Value Added (TiVA) 2021 Database* and the *IMF Export Diversification and Quality Databases*, I examine the causal impact of participating in GVC trade on export quality upgrading with a sample of 61 countries, 28 aggregated ISIC industries from 1995 to 2014 using Generalized Method of Moments (GMM). Second, I conduct detailed analyses to present the heterogeneous effects of increasing GVC linkages on export quality upgrading among country and industry groupings. Third, I construct a country-industry upstreamness measure using the *OECD Inter-Country Input Output (ICIO) Database* to examine the varied effects along different positions of the value chains.

This article makes three contributions. First, since GVC trade is a country-industry phenomenon, I create an SITC-ISIC concordance to aggregate the product-level export quality measure in the IMF dataset to the ISIC-industry level in the TiVA database. This allows me to estimate the impact of GVC trade on export quality upgrading at the country-industry-year level. Second, my essay joins a group of scholars' research on the intersection of GVC trade and the quality upgrading aspect of structural transformation. This essay presents more comprehensive analyses and empirical evidence at the country and industry level compared to the existing literature. In terms of heterogeneous effects across countries, I examine the impact by countries' development status, development trajectories, and analyze the subsample of East Asia and Pacific countries due to this region's tremendous economic growths during the sample period. In terms of sectoral heterogeneities, I analyze the interaction effect of GVC trade with manufacturing industries, the interaction effect of GVC trade with R&D intensity, and whether sectoral share of differentiated products is a statistically significant predictor of the impact of GVC trade on quality upgrading. Third, to the best of my knowledge, this paper is the first to examine the impact of trade in value-added on quality upgrading by estimating a country-industry's position in the global production system. By constructing the upstreamness measure which encompasses all country-industry pairs covered in the TiVA database, I provide empirical evidence on the question "How does the impact of GVC trade on export quality upgrading vary by a country's and industry's position within the production chain?". The results have intuitive policy implications: Country-industry pairs in different positions along the value chains should pursue different development strategies and participate in GVC trade in dynamic, forward-thinking ways.

This paper is related to the strand of literature which infers product quality using unit value in the trade flow data. Using product-level U.S. import data, Schott (2004) finds that within-product unit values vary systematically based on exporter relative factor endowments and exporter production techniques. Hummels and Klenow (2005) examine whether intensive margins (exporting larger quantities of each good), extensive margins (exporting a wider set of goods), or exporting higher quality goods can be used to explain why larger economies export more in absolute terms. The quality margin is not explicitly observable but can be inferred by examining projections of price and quantity on GDP and its components. They find that extensive margins account for around 60 percent of the increase in exports. In addition, wealthier countries export larger quantities at modestly higher prices. The combination of higher prices and larger quantities suggests that these exporters produce higher quality goods. Kaplinsky and Readman (2005) measure comparative innovation performance using data on unit prices and market shares. Using these data as a metric of upgrading, the authors suggest that firms which successfully engage in innovation can expect to maintain relatively higher prices for their output without suffering from declining market shares.

Literature which examines the determinants of output or export quality upgrading suggest that R&D, FDI, and the quality of inputs play important roles. Grossman and Helpman (1993) theorize that a firm would invest in R&D to climb up the "quality ladder" of intermediate products and extract monopoly profits as a reward for prior investment. Kugler and Verhoogen (2008) extend the dynamic industry model with heterogeneous firms by Melitz (2003) and present an empirical investigation of the quality-complementarity hypothesis: Input quality and plant productivity are complementary in generating output quality. Using representative product-level data from Colombian manufacturing plants, the authors find that within narrowly defined sectors, a firm's export status is positively correlated with input prices (which reflects input quality) and output prices. Exploiting an exogenous shock of input trade liberalization in India, Goldberg et al. (2010) find that 31 percent of the new products introduced by domestic Indian firms can be attributed to increased firm access to new input varieties made available due to the input tariff reductions. Similarly, Bas and Strauss-Kahn (2015) show that in response to input tariff reductions between 2000 and 2006, Chinese firms imported more varieties of inputs from the most advanced economies. Among these firms, export prices rose for firms exporting output to high-income countries. Intuitively, Chinese firms exploited the input tariff cuts to obtain higher quality inputs in order to upgrade the quality of outputs. Amighini and Sanfilippo (2014) explore the effect of imports and FDI on the upgrading of African exports and find evidence that South-South FDI improves the average quality of manufacturing exports.

My paper also joins the existing literature which explicitly examines the relationship between GVC trade and export quality. Kummritz and Winkler (2017) highlight the mediating role of policies which facilitate economic upgrading through GVC integration. Using the OECD ICIO data across seven years and a 1995-2011 sample of 40 countries from the *World Input-Output Database (WIOD)*, the authors show that GVC integration is connected to economic upgrading, measured by a country's domestic value added. In addition, regression results using the OECD sample suggest that the gains from GVCs are transmitted more through forward GVC integration, and many results are driven by high- and upper-middle-income countries. Using a highly disaggregated dataset of product-level exports from 122 countries, Ndubuisi and Owusu (2021) find that both backward and forward GVC participations positively affect the quality of exported products and result in the quality level being closer to the quality frontier. The authors show that while this result holds in the sub-sample of developed economies, developing economies only benefit from backward GVC participation. Examining the long-run impact of GVC participation for 58 countries from 1970 to 2008 using panel regressions, Pahl and Timmer (2020) find strong support for the positive impact of GVC on economic upgrading, measured by productivity growth in the formal manufacturing sector. The impact is stronger the larger the gap from the global productivity frontier is, suggesting that a catch-up effect is present in the data. Literature including Taglioni and Winkler (2016) points out that establishing the exogeneity of GVC participation to economic upgrading is challenging due to different sources of endogeneities, including reverse causality, omitted variable bias, and dynamic endogeneity. Instead of positing that participating in GVC trade gives rise to economic upgrading, one could argue that an increasing GVC trade integration is endogenous to a rise in production sophistication. In terms of omitted variable bias, one could reasonably argue that GVC trade and upgrading can both be attributed to many omitted factors, including but not limited to institutions, foreign direct investment, and R&D. Dynamic endogeneity is present when the current value of independent variables are impacted by the past values of the dependent variable, resulting in biased estimates.

My paper contributes to the above-mentioned literature and distinguishes from the existing literature in several ways. First, although many of my empirical findings are consistent with those in Kummritz and Winkler (2017), I show that backward GVC participation can have a significant impact on export quality upgrading once we take into account the position of a country-industry pair in the production line. Second, while Ndubuisi and Owusu (2021) achieve the largest coverage of countries (122) using the *Eora MRIO I-O Database*, it extrapolates GVC indicators especially for developing countries without comprehensive input-output tables, making the data less reliable. Instead, I opt for the TiVA database to take advantage of data accuracy at the expense of more comprehensive country coverage. Third, the panel regression estimator used in Pahl and Timmer (2020) is subject to above-mentioned endogeneity concerns. In my paper, I employ the two-step system-GMM technique to estimate the dynamic panel data (DPD) model, in which the dependent variable ln(Export Quality) is a function of its lagged value, lagged GVC indicators, and lagged values of the control variables, all with a one-year lag. Compared to the panel regression estimator, GMM is a more suitable methodology to control for reverse causality, omitted variable bias, and dynamic endogeneity. This mitigates the endogeneity concerns mentioned in Taglioni and Winkler (2016).

I find consistent empirical evidence that increasing GVC participation has a positive and statistically significant marginal effect on export quality upgrading. This effect is pronounced and robust across specifications for forward GVC participation, while that of backward GVC participation is mostly absent. In the baseline scenario, at the country-industry level, for every one percentage point increase in the forward GVC participation in the current period, the export quality one-period ahead increases by 0.64 percent. The effect of GVC trade on export quality upgrading is larger for country-sector pairs whose export qualities are already higher, meaning that no catch-up effect is observed in the sample. In terms of heterogeneities among countries, the impact of increasing forward GVC participation on export quality is positive and significant among both advanced economies and EMDEs, among countries which have experienced an improvement in income status within the sample period, and among the subgroup of East Asia and Pacific countries. The effect of a one percentage point increase in forward GVC participation on export quality upgrading is over twice as large among the EMDEs than among the developed economies (0.68 percent versus 0.30 percent). In terms of heterogeneous impact among sectors, three patterns can be observed. First, compared to non-manufacturing sectors, an increase in the forward GVC participation in manufacturing sectors significantly leads to an increase in export quality. Unsurprisingly, the export quality upgrading benefits of GVC participation are limited to participating manufacturing sectors. Second, compared to sectors with higher R&D intensities, an increase in forward GVC linkages in sectors with low R&D expenditure shares links to a decrease in export quality. This indicates that firms have a choice to either engage in R&D to upgrade, or not devote resources to R&D and experience the adverse spillovers when participating in GVC trade. Third, increasing the share of sectoral differentiated products is a significant factor for export quality upgrading: An increase in the production share of differentiated products by ten percentage points is associated with an improvement in export quality by 0.4 percent. Lastly, subsample analyses by upstreamness category indicate that the impact of participating in GVCs on an increase in export quality is statistically significant across all positions on the value chains. More interestingly, an increase in forward GVC participation is driving the significant impact on export quality upgrading when a country-industry pair is in either a downstream or a relatively upstream position in the value chain. On the other hand, for country-industry pairs in extremely upstream positions of the production line, it is an increase in backward GVC participation that is driving the improvement in export quality. Regression results indicate that an increase in GDP per capita, investment as a share of GDP, foreign direct investment as a share of GDP, and human capital positively contribute to export quality upgrading with a delayed effect, and an increase in capital stock has the opposite effect. The effect of GDP per capita is consistent and robust across specifications and analyses.

The remainder of this paper is structured as follows. Section 2 reviews a theoretical model on endogenous growth by Keller (2002), which provides a R&D-driven model of economic growth and intermediate inputs which serves as the theoretical foundation for this article. Section 3 details the sources and calculations of the variables used in the regressions, as well as illustrates initial data visualizations. Section 4 explains the baseline specifications and the empirical methodology. Section 5 presents the empirical results from the baseline specifications and the heterogeneous effects across countries, industries, and country-industry's upstreamness positions along the value chains. Section 6 discusses the policy implications and concludes.

2 Theoretical Foundation

The effect of technology transmission through trade in intermediates on export quality upgrading can be explained by theories on trade and endogenous technological change. There can be many potential channels of technology transmission, including R&D, FDI, and licensing and patents, to list a few. In this section, I reference Keller (2002), which presents a R&D-driven model of technological growth and intermediate inputs that is relevant in the GVC trade context. In this model, R&D spending results in new technology in the form of new, specialized intermediate goods. In the context of trade in intermediates, domestic and foreign firms can purchase a wider range of new intermediate goods, through which technology spillovers occur both within- and between-industry, domestically and abroad. This results in an increase in economic growth, modeled as an increase in productivity. By integrating an analysis of domestic and international technology transmission, the author highlights that knowledge transmission through input-output and imports relations is crucial, and that positive spillover effects are generated from R&D within-industry, R&D in other domestic industries, as well as R&D in foreign industries.

Specifically, assume that long-run growth is endogenously determined by R&D investments, and that technology is diffused through trade in intermediate inputs. Further assume that a country's output is produced with a Cobb-Douglas production function:

$$z = Al^{\alpha}d^{1-\alpha}, 0 < \alpha < 1, \tag{1}$$

where A is a positive constant, l refers to labor, and d is a composite input consisting of horizontally differentiated goods x of variety s:

$$d = \left(\int_0^{n^e} x(s)^{1-\alpha}\, ds \right)^{\frac{1}{1-\alpha}}. \tag{2}$$

The variable n^e refers to the range of intermediate inputs used in this country's production, which might be different from n, the range of intermediate inputs this country produces. Increasing businesses' resource allocation to $R(D)(\chi)$ increases n. Assume that there is no depreciation of R&D capital, the range of intermediates at time T is:

$$n(T) = \int_{-\infty}^{T} \chi(t)\, dt, \tag{3}$$

which is the total amount of resources devoted to R&D up to time T.

The goods $x(s)$ are differentiated capital goods produced with foregone consumption. Let $\tilde{k}$ be capital, which is the cumulative stock of foregone consumption. In equilibrium, intermediate goods are transformed into capital with a linear production technology:

$$\tilde{k} = n\overline{x}, \tag{4}$$

where $\overline{x}$ is the level at which intermediate capital goods are systematically produced. Assume that intermediate goods are not traded in a closed economy, so that $n^e = n$; therefore, $\tilde{k} = n^e\overline{x}$. Substituting this expression back to equation (1) and (2), we have:

$$z = A(n^e)^{\alpha} l^{\alpha} \tilde{k}^{1-\alpha}. \tag{5}$$

Define total factor productivity (TFP) as $F \equiv A(n^e)^{\alpha}$, meaning that:

$$log(F) = log(A) + \alpha log(n^e). \tag{6}$$

Equation (6) indicates that TFP is positively associated with the range of intermediate inputs employed. In an open economy with many countries, $c = 1, ..., C$, countries engage in imports and exports of intermediate goods. Extending this framework to a multi-sector setting, the composite input for country c's industry $i = 1, ..., I$ has the following expression:

$$d_{ci} = \left(\int_0^{n_{ci}^{ci}} x_{ci}^{ci}(s)^{1-\alpha}\, ds + \int_0^{n_{ck}^{ci}} x_{ck}^{ci}(s')^{1-\alpha}\, ds' + \int_0^{n_{hi}^{ci}} x_{hi}^{ci}(\check{s})^{1-\alpha}\, d\check{s} + \int_0^{n_{hk}^{ci}} x_{hk}^{ci}(\tilde{s})^{1-\alpha}\, d\tilde{s} \right)^{\frac{1}{1-\alpha}}, \tag{7}$$

$\forall c, i$, where $h \neq c$ and $k \neq i$. A subscript represents the country and industry where the intermediate good is produced, and a superscript represents the country and industry where the intermediate is employed. The terms in equation (7) stand for own-industry intermediates (from country-industry combination ci), domestic intermediates from other industries (subscript ck), foreign intermediates in the same industry (subscript hi), and foreign intermediates from other industries (subscript hk), respectively. The composite input d for each country-industry is produced from intermediates sourced domestically and internationally, both within and beyond its own industry.

This theoretical framework complements my empirical studies as it models some of the distinct features of GVC trade and its impact on productivity growth. First, it considers the role of input-output relations to capture trade links between countries and industries. Second, it can be reasonably inferred from this model that both forward and backward GVC participation can have an effect on an increase in productivity. In terms of the forward GVC linkage, a country can explicitly contribute to an increase in productivity by spending on R&D and inventing new product varieties. In terms of the backward GVC linkage, each country can employ a wider range of intermediate goods than what can be produced domestically, therefore implicitly benefiting from the new foreign technology embodied in the intermediate imports. These channels provide rationales for why GVC trade can directly and indirectly facilitate economic growth. Third, my empirical results on the R&D intensity analyses and on the country-industry upstreamness analyses are consistent with the intuition and implications in Keller (2002). Countries that participate in GVC trade with low R&D intensities will experience a wider export quality gap from the industry quality frontier. In addition, country-industry pairs in downstream or relatively upstream positions can experience export quality upgrading through increasing forward GVC linkages, while those in extremely upstream positions can experience export quality upgrading through increasing backward GVC linkages.

3 Data

3.1 Data Description

To empirically test the impact of participating in GVC trade on export quality upgrading, I rely on multiple data sources detailed below.

First, I access the country-industry level GVC principal indicators from the *OECD TiVA (2021) Database*, generated using the OECD ICIO tables. The indicators cover the period from 1995 to 2018, which include data for 66 economies and the rest of the world, a selection of region aggregates, and 45 unique industries and associated aggregates based on the 2-digit ISIC Rev.4 classification. Besides the TiVA database, other major GVC datasets include the Eora Multi-Region Input-Output Table, WITS

WDR 2020 GVC Data, Asian Development Bank (ADB) Input-Output Tables, and the University of Groningen GVC Database. Due to the fact that Eora includes imputed GVC indicator values for EMDE countries whose input-output tables are not publicly available, and that the TiVA database provides a more comprehensive country-industry coverage than the other databases, I opt for TiVA to take advantage of data accuracy at the expense of maximizing the number of countries covered.

Appendix Figure A1 and Appendix Figure B1 detail the country and industry coverage in TiVA (2021). In terms of country coverage, 38 out of the 66 economies are OECD countries, and 28 are non-OECD economies of different development status. Among the 45 industries covered, 17 are manufacturing sectors, and 20 are services sectors. In 2018, the sum of 66 economies represented 93 percent of the global GDP, 92 percent of the exports, and 90 percent of the imports. However, one crucial caveat is that due to data limitations, low-income countries and certain geographical regions are severely under-represented. Only seven Latin America and the Caribbean countries, as well as one African country (South Africa), are included in TiVA (2021), while none of the low-income economies (based on the World Bank Country and Lending Groups income classification) is included. This means that the EMDEs in my sample are middle-income countries, and that we should be cautious about applying the findings for EMDEs to lower-income developing economies.

My main independent variables of interest capture the country-industry level value-added content as a share of gross exports from both a supplier's and a user's perspective. *Forward GVC Participation* represents the supplier's perspective in GVC trade, defined as country c's domestic value-added content embodied in the gross exports of industry i in foreign countries, as a percentage of country c's total gross exports. Intuitively, it measures the amount of value-added contributed by the source country c in the gross exports in industry i of foreign country p, as a share of the source country's total gross exports. In TiVA (2021), it is calculated as:

$$ForwardGVCParticipation_{c,i} = \frac{\sum_p EXGRBSCI_{c,i,p}}{EXGR_c} * 100\%, \tag{8}$$

where $EXGRBSCI_{c,i,p}$ is the total value-added from country c embodied in the gross exports of industry i in foreign country p, and $EXGR_c$ is country c's total gross exports.

Backward GVC Participation represents the user's perspective in GVC trade, defined as the foreign value-added contribution to the receiving country c's gross exports in industry i, as a percentage of country c's total gross exports. Intuitively, it measures the amount of value-added contributed by the foreign country p in the gross exports in industry i of the receiving country c, as a share of the receiving country's total gross exports. It is calculated as:

$$BackwardGVCParticipation_{c,i} = \frac{\sum_p EXGRFVA_{c,i,p}}{EXGR_c} * 100\%, \tag{9}$$

where $EXGRFVA_{c,i,p}$ refers to the foreign value-added content of gross exports by industry.

As is common practice in the GVC literature, I create the variable *GVC Participation Index* as the sum of *Forward GVC Participation* and *Backward GVC Participation*. This measure reflects a country-industry's engagement in a vertically fragmented production, both as a user of foreign value-added for its own exports and as a supplier of domestic value-added embedded in intermediate goods and services used in foreign countries' exports.

Second, I access the export quality data from the *IMF Export Diversification and Quality Databases*, produced by Henn et al. (2013).[3] The quality estimates are constructed from a large trade dataset and covers 166 countries from 1963 to 2014. Using the *COMTRADE Database*, the trade dataset is created by supplementing importer-reported data by exporter-reported data where the former has missing values. The estimations are built upon 55.8 million observations on bilateral trade values and quantities at the SITC 4-digit Rev.1 level. A unit value is obtained for each product category. The total number of "SITC 4-digit-plus" product categories in this dataset is 851.

The authors estimate the export quality using this trade dataset (which contains trade prices, values, and quantities) as well as a series of gravity-style variables from various sources, including preferential trade agreements data from the WTO's *Regional Trade Agreements Database*, gravity variables from CEPII, and income per capita data from the *Penn World Tables* (PWT) version 7.1. Then, quality is estimated from unit values, using a methodology modified from Hallak (2006) to achieve the largest country and time coverage possible.

The estimation methodology is summarized as follows. First, the trade price of a

[3]For detailed information on how the IMF export quality measure is generated, please refer to this paper.

good (unit value) is assumed to be determined by the following relationship:

$$ln(p_{mxt}) = \zeta_0 + \zeta_1 ln(\theta_{mxt}) + \zeta_2 ln(y_{xt}) + \zeta_3 ln(Dist_{mx}) + \xi_{mxt}, \tag{10}$$

where the subscripts m, x, and t stand for importer, exporter, and time, respectively. Intuitively, the trade price is determined by three factors: the unobserved quality, exporting country's per-capita income y_{xt}, and the distance between the importer and the exporter $Dist_{mx}$.

Next, the authors specify a quality-augmented gravity equation for each product, as the preference for quality and trade costs may differ across products. The quality-augmented gravity equation is as follows:

$$ln(Imports_{mxt}) = \alpha ln(Dist_{mx}) + \beta I_{mxt} + \delta ln(\theta_{mxt}) ln(y_{mt}) + ImFE + ExFE + \epsilon_{mxt}, \tag{11}$$

where I_{mxt} is a vector of gravity-style variables, θ_{mxt} is the exporter-specific quality parameter, y_{mt} is the importer's per-capita income, and *ImFE* and *ExFE* stand for the importer and exporter fixed effects, respectively.

Then, the authors substitute the expression for $ln(\theta_{mxt})$ from equation (10) into the unobservable quality parameter in equation (11). Rearranging the terms yields the equation below:

$$\begin{aligned} ln(Imports_{mxt}) = \alpha Dist_{mx} + \beta I_{mxt} + ImFE + ExFE + \zeta_1' ln(p_{mxt}) ln(y_{mt}) + \zeta_2' ln(y_{xt}) \\ ln(y_{mt}) + \zeta_3' ln(Dist_{mx}) ln(y_{mt}) + \xi_{mxt}', \end{aligned} \tag{12}$$

where $\zeta_1' = \frac{\delta}{\zeta_1}$, $\zeta_2' = -\frac{\delta\zeta_2}{\zeta_1}$, $\zeta_3' = -\frac{\delta\zeta_3}{\zeta_1}$, and $\xi_{mxt}' = -\frac{\delta\zeta_0 + \delta\xi_{mxt}}{\zeta_1} ln(y_{mt}) + \epsilon_{mxt}$. Equation (12) is estimated separately for each of the 851 4-digit-plus SITC product categories in the trade dataset. Last, using the coefficient estimates derived above, the authors estimate quality as the unit value with adjustments for differences in production costs and for the selection bias due to the importer-exporter distance. The estimation equation is as follows:

$$QualityEstimate_{mxt} = \delta ln(\theta_{mxt}) = \zeta_1' ln(p_{mxt}) + \zeta_2' ln(y_{xt}) + \zeta_3' ln(Dist_{mx}). \tag{13}$$

This procedure generates estimated quality values for 835 SITC 4-digit-plus product categories for each importer-exporter-year observation without missing data. The export quality index is normalized by the 90$^{\text{th}}$ percentile in the product-year combination: A value of 1 represents a quality level in line with the global quality frontier, taken to be the quality score at the 90$^{\text{th}}$ percentile observed among all exporters. The quality values generally range from 0 to 1.2.

I am interested in analyzing the impact of participating in GVC trade on export quality upgrading at the country-industry level. To aggregate the SITC Rev.1 product level export quality index to the 2-digit ISIC Rev.4 industry classification, I create a crosswalk which maps product-level export quality data to industry-level GVC indicators using concordances from the UN Trade Statistics,[4] [5] and Eurostat RAMON.[6]

In addition to the GVC indicators, I include six additional regressors in the analyses: GDP per capita, foreign direct investment (FDI) net inflows as a share of GDP, investment (a.k.a. gross capital formation) as a share of GDP, human capital, institutional quality, and capital stock (at constant prices). I hypothesize that each of the six regressors contributes to export quality upgrading with a lagged effect, and that the coefficient on each regressor is positive. First, countries with higher GDP per capita levels have more resources and productive capacities to produce higher-quality goods. Second, according to Loungani and Razin (2001), FDI embodies technological transfer especially in the form of new varieties of capital inputs, which is not achievable through financial investments or trade in goods and services. Countries with higher FDI net inflow shares may improve the technology and quality of products through the introduction of foreign capitals and expertise. In my regression analyses, the FDI variable represents the share of GDP on inward direct investment made by non-resident investors. Third, countries with larger shares of investment as a percentage of GDP accumulate capital stocks more rapidly, which lead to a higher level of productivity. Data on GDP per capita, FDI, and investment are accessed from the World Bank *World Development Indicators*. Fourth, an increase in human capital provides the educational foundation and technical know-how to climb the quality ladder. Human capital data is accessed from the PWT version 10.01.[7] The variable is constructed based on the average years of schooling from Barro and Lee (2013) and an assumed rate of return on education by Psacharopoulos (1994), based on Mincer equation estimates around the world. Fifth, institutional quality measures a country's quality of governance. Better institutions can encourage competitions among firms

[4] https://unstats.un.org/unsd/classifications/Family/Detail/14
[5] https://unstats.un.org/unsd/classifications/Econ#Correspondences
[6] https://ec.europa.eu/eurostat/web/metadata/classifications
[7] https://www.rug.nl/ggdc/productivity/pwt/?lang=en

to increase efficiency and develop more cutting-edge technologies to stand out from the competition and enjoy oligopolistic or monopolistic profits, potentially leading to higher export qualities. Data on institutional quality is accessed from the *Polity5* Project by Center for Systemic Peace.[8] Defined as "executive constraints", it represents the extent of institutionalized constraints on the decision-making powers of chief executives.[9] Lastly, economies with a large amount of capital stock tend to be more capital-abundant, therefore can produce more sophisticated products. Data on capital stock (at constant 2017 national prices) is also accessed from the PWT.

The full sample is an unbalanced panel with 31,242 observations, which consists of data on 61 countries, 28 industries at the 2-digit ISIC Rev.4 classification and covers the period 1995-2014. Table 1 provides descriptive statistics for the variables.

Table 1. Summary Statistics

Variables	Observations	Mean	Std. Deviation	Min.	Max.
Forward GVC Participation (%)	31,242	0.57	0.92	0	16.77
Backward GVC Participation (%)	31,242	0.71	1.50	0	25.51
GVC Participation Index (%)	31,242	1.28	2.06	0	27.84
Export Quality at ISIC Level	31,242	0.90	0.11	0.17	1.48
GDP Per Capita (PPP)	31,242	28,214	19,285	708.50	120,648
Human Capital Index	31,242	2.86	0.56	1.43	3.73
FDI, Net Inflows (% of GDP)	31,191	5.58	15.57	-57.53	279.40
Investment (% of GDP)	30,877	24.22	5.49	1.16	46.66
Institutional Quality	31,242	5.66	6.17	1	7
Capital Stock (USD Million)	31,242	4,896,676	9,023,806	18,563	64,118,472
Differentiated Products (at ISIC Level, %)	31,242	62.60	28.91	15.38	100
Number of Country-Industry Units	1,631				
Binary Variables					
EMDE Countries (IMF WEO)	31,242	0.47	0.50	0	1
Manufacturing Industries	31,242	0.64	0.48	0	1
Low R&D Intensity	31,242	0.26	0.44	0	1
Income Level Improvement (World Bank)	31,242	0.45	0.50	0	1

Notes: Summary statistics are based on the *TiVA (2021)* GVC indicators, which covers data from 1995 to 2018 on 66 economies and 45 industries based on the 2-digit ISIC Rev.4 classification; *IMF Diversification and Quality* database, which covers data from 166 countries from 1963 to 2014; the World Bank *World Development Indicators*; *Penn World Table*; and the *Polity5 Project*. The number of differentiated products are calculated based on Rauch (1999). The binary variables are generated based on the IMF WEO code; OECD TiVA (2021); the World Bank Group country classifications by income level; and Galindo-Rueda and Verger (2016). In the baseline specification, the sample is an unbalanced panel with 31,242 observations, which consists of data on 61 countries, 28 2-digit ISIC Rev.4 industries, and covers the period 1995 to 2014.

[8] https://www.systemicpeace.org/polityproject.html

[9] According to the Polity5 manual, the variable has seven incremental categories, with "1" being "unlimited authority" ("there are no regular limitations on the executive's actions", pp.24), and "7" being "executive parity or subordination" ("accountability groups have effective authority equal to or greater than the executive in most areas of activity", pp.25).

3.2 Descriptive Statistics and Initial Data Visualization

3.2.1 Stylized Facts on GVC Participation across Countries, Industries, and Time

This section illustrates the stylized facts of the GVC indicators for the 61 countries[10]

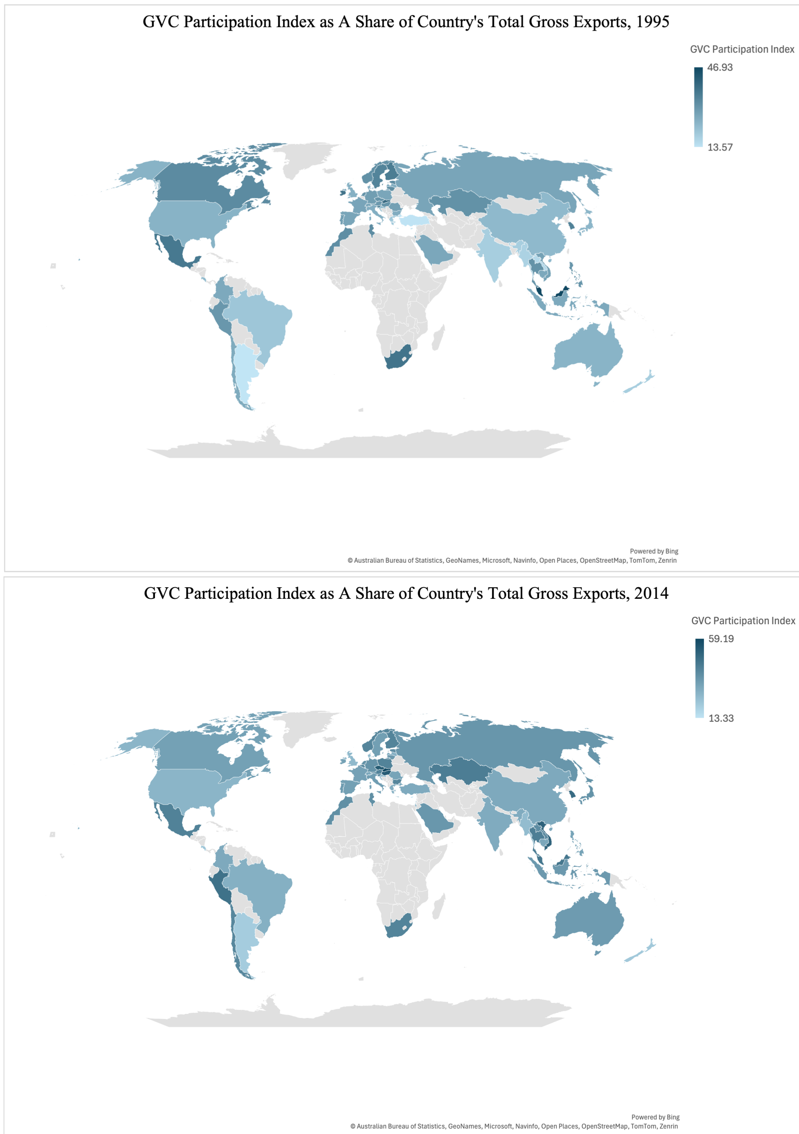


Figure 2. GVC Participation Index as A Share of Gross Exports, 1995 vs. 2014

Notes: Using TiVA (2021), I sum up the *forward and backward GVC participation* and aggregate the values across 28 ISIC industries to create the country-level GVC Participation Index measure.

[10]Note that the sample in this paper is mainly constrained by the GVC data. However, Brunei Darussalam, Iceland, Hong Kong, Malta, and Chinese Taipei are omitted from the sample as data on export quality and institutional quality is missing for one or multiple of these countries.

in the full sample. Figure 2 maps the intensiveness of country-level *GVC Participation Index* as a share of each country's total gross exports in 1995 versus 2014. Overall, the global economy has become considerably more integrated in terms of participating in GVC trade. The median of *GVC Participation Index* rises from 27.3 percent in 1995 to 35.5 percent in 2014. Sizable increases in GVC participation can be observed among countries in the European Union, Asia, South America, and a few other countries in the Southern Hemisphere.

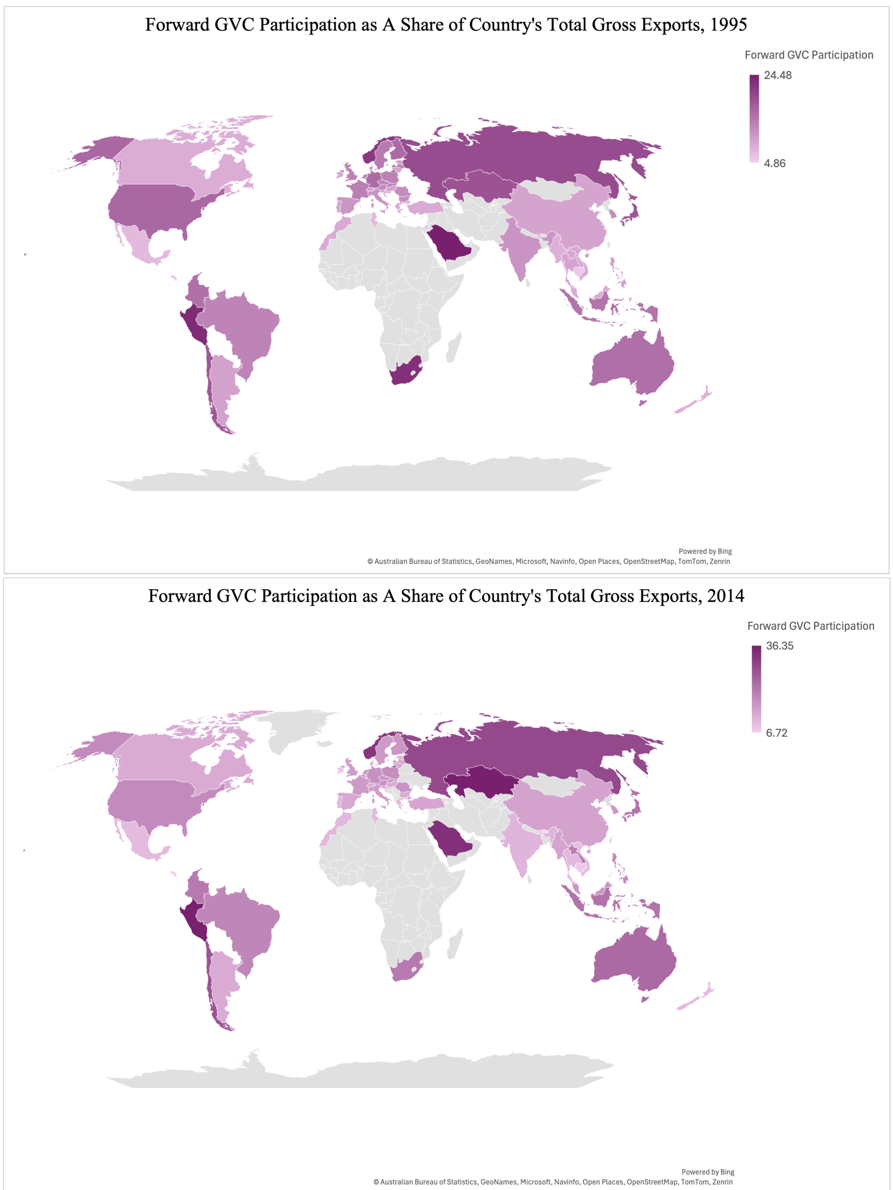


Figure 3. Forward GVC Participation as A Share of Gross Exports, 1995 vs. 2014

Separating the *GVC Participation Index* into *Forward GVC Participation* and

Backward GVC Participation, I depict the intensity of country-level forward and backward GVC linkages in Figure 3 and Figure 4, respectively. While both seem to have contributed to the rise in global trade integration, a more drastic increase in forward GVC linkages is evident in most of the countries.

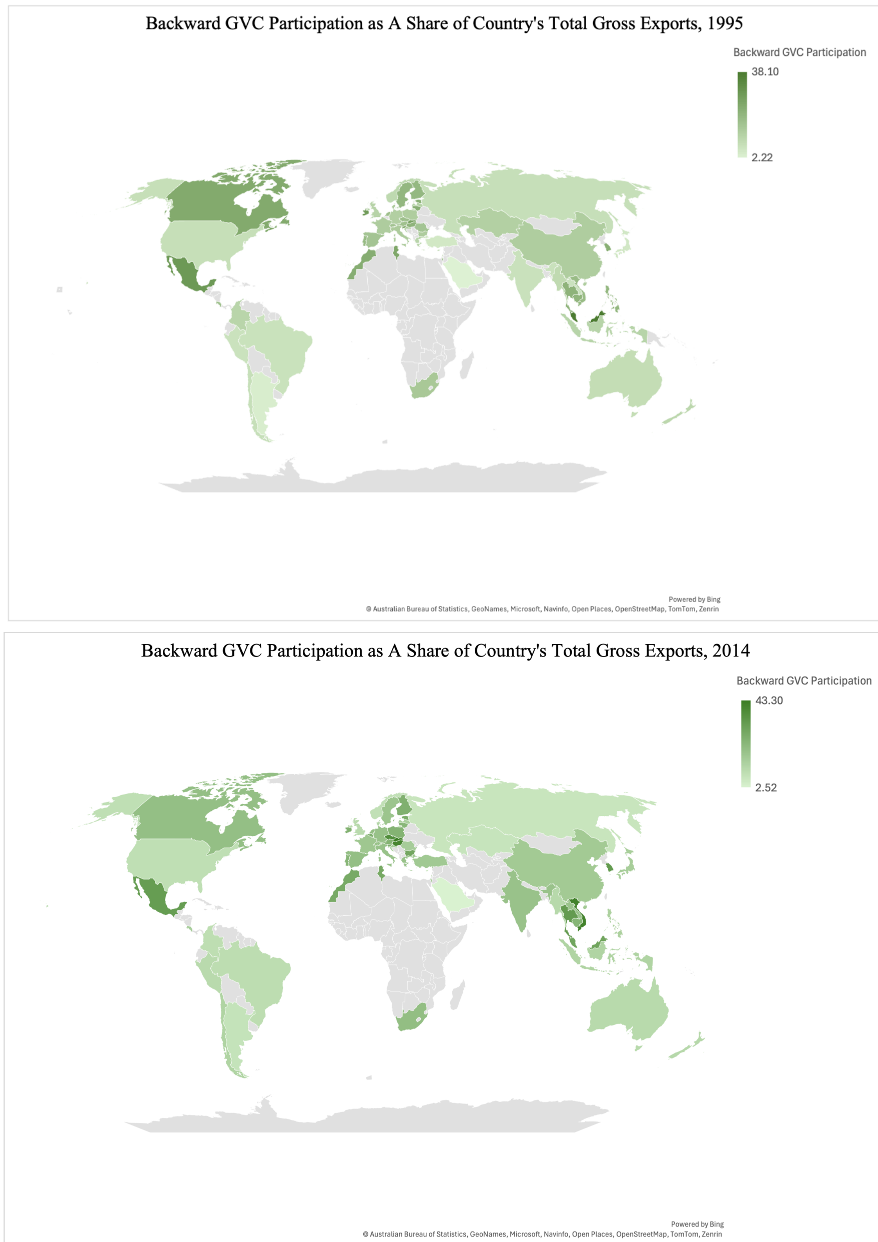


Figure 4. Backward GVC Participation as A Share of Gross Exports, 1995 vs. 2014

Interested in the GVC participation breakdown by country in 1995 vs. 2014, I depict the *GVC Participation Index* for advanced economies and EMDEs in Figure 5.

Several patterns can be observed. First, among all advanced economies with complete data, all economies except for Cyprus, Ireland, Israel, Singapore, and Sweden have experienced an increase in GVC trade. Among EMDEs, only Costa Rica and Malaysia recorded a lower GVC participation value in 2014 compared to 1995. More interestingly, countries including Czech Republic, Slovak Republic, Hungary, and Vietnam have experienced over 50 percent increase in GVC trade within 20 years. This suggests that for these Soviet-bloc nations in Eastern Europe and Asia, the drastic increases in GVC trade simply reflect their integration into the world economy.

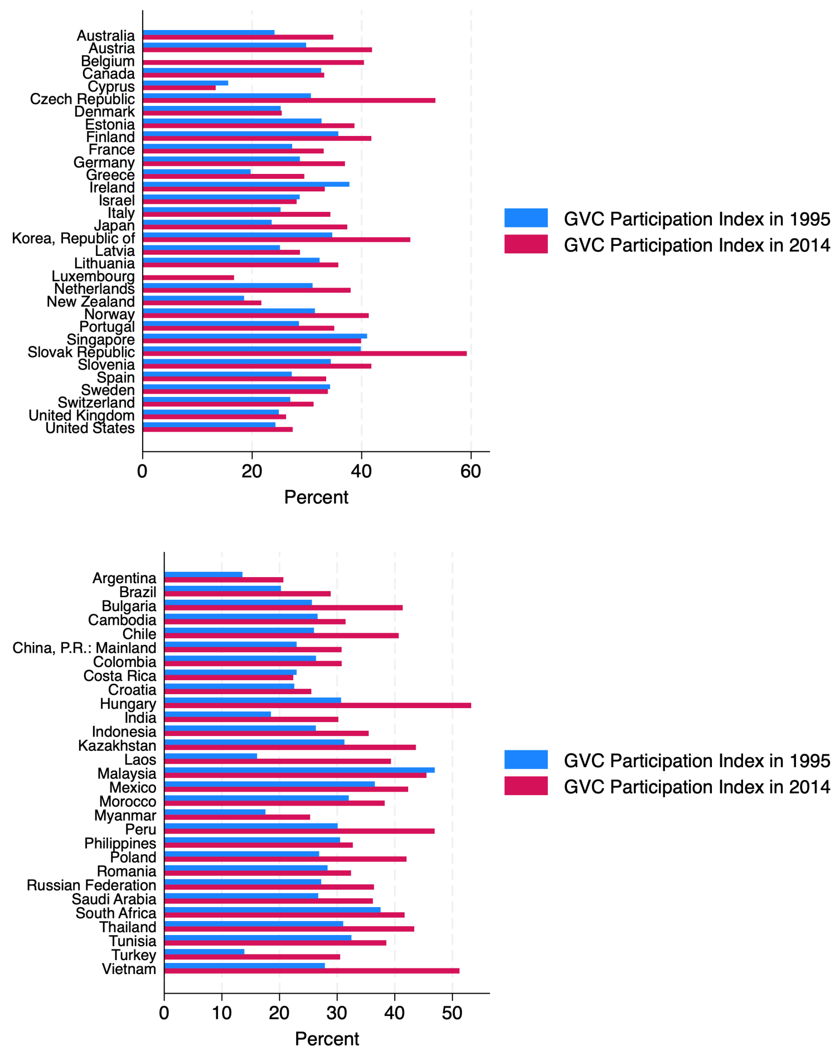


Figure 5. GVC Participation Index for Advanced Economies vs. EMDEs, 1995 vs. 2014

Notes: Calculated using TiVA (2021). Methodology used is consistent with that in Figure 2. There are 32 advanced economies and 29 EMDEs in the sample.

Figure 6 shows the time trends of *Forward* and *Backward GVC Participation* from 1995 to 2014 for both advanced economies and EMDEs. Compared to EMDEs, advanced economies started off with higher values for both *Forward* and *Backward GVC Participation* in 1995, and the same is true by 2014. However, EMDEs experienced a higher growth in *Forward GVC Participation* than developed economies, having surpassed the value of advanced economies for several years. In addition, advanced economies responded more negatively to economic shocks such as the 2007-2008 financial crisis and the 2014 commodity crash in terms of *Backward GVC Participation*. For EMDEs, the adverse events affected the *Forward* and *Backward GVC Participation* by similar magnitude.

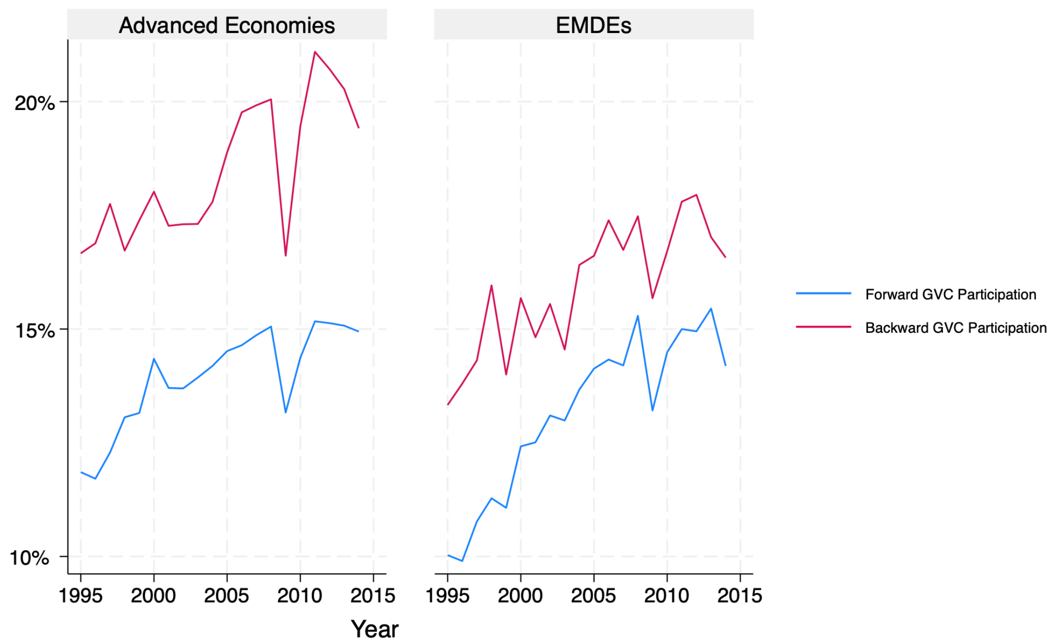


Figure 6. Time Series of Forward and Backward GVC Participation, 1995-2014

To examine the heterogeneities of GVC participation among sectors, I plot the median of *Forward* and *Backward GVC Participation* across countries for each 2-digit ISIC Rev.4 industry over the sample period in Figure 7. Overall, industries with higher forward GVC linkages also tend to have higher backward GVC linkages. The values of *Forward* and *Backward GVC Participation* are the highest among the manufacturing sectors, followed by agriculture, hunting, and forestry; mining; and select services sectors.[11] The median values of forward linkages are the highest for

[11]Note that the extent of *Forward* and *Backward GVC Participation* in my sample may be under-

the following sectors: motor vehicles; computer, electronic, and optical equipment; machinery and equipment; chemical and chemical products; and basic metals. Sectors with the largest shares of backward GVC linkages include basic metals; chemical and chemical products; coke and refined petroleum products; food products, beverages and tobacco; and machinery and equipment. One reasonable explanation is that goods produced in the manufacturing sectors tend to be more technologically sophisticated than sectors which involve processing raw materials. Therefore, the manufacturing sectors contribute a higher share of value-added to the value chains, which means a higher *Forward GVC Participation* by definition. On the other hand, raw material processing sectors rely on importing a larger share of foreign value-added to transform the inputs into finished goods, which explains the higher *Backward GVC Participation*.

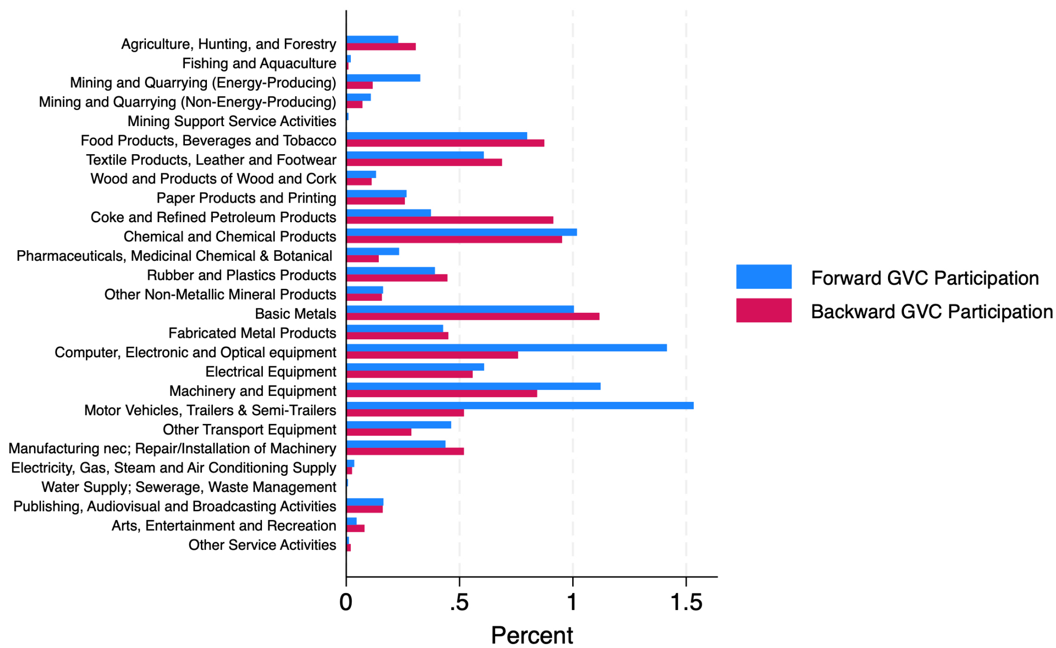


Figure 7. Median Forward and Backward GVC Participation by Industry, 1995-2014

Notes: Calculated using OECD TiVA (2021). For every ISIC Rev.4 industry in the sample, I take the median of forward and backward GVC participation across all countries between 1995 and 2014. There are 27 industries in this chart; industry "Professional, scientific, and technical activities" (code "D69T75") is omitted due to missing values.

---

representing the services sectors, as the *IMF Export Diversification and Quality Database* mainly has data on the export quality of goods rather than services.

3.2.2 Stylized Facts on Export Quality across Country and Time

This section presents the heterogeneities of export quality using the *IMF Export Diversification and Quality* Database. Using country-level export quality measure in the IMF data, I create two maps which reflect the evolution of export quality in 1995 and in 2014. The index is normalized such that a value of 1 represents a quality value at the 90$^{\text{th}}$ percentile, which is considered the global quality frontier.

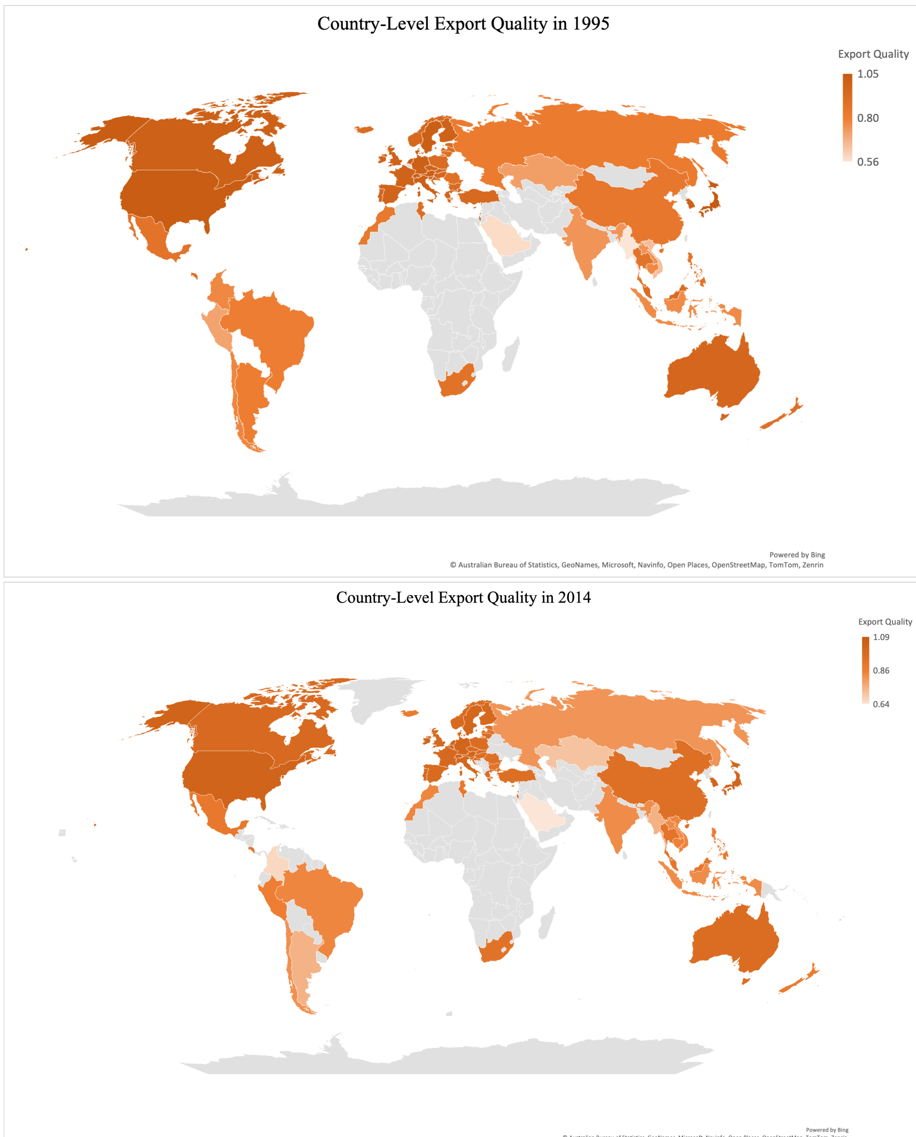


Figure 8. Country-Level Export Quality in 1995 vs. 2014

Notes: Maps are constructed using the *IMF Export Diversification and Quality Database*.

Figure 8 exhibit several patterns. First, I observe apparent heterogeneities across countries. Country-level export quality values range from 0.56 to 1.09, with Saudi Arabia consistently having the lowest values in both years. Unsurprisingly, developed economies have higher export qualities. Second, between 1995 and 2014, few changes are observed among developed economies, while mixed development patterns are shown among EMDEs. Asian countries including China, India, Vietnam, and Myanmar have seen improvements in export qualities. On the other hand, export qualities have noticeably regressed in Kazakhstan, Morocco, and several Latin American countries, including Colombia, Brazil, and Argentina. These patterns coincide with the fact that Latin American countries have experienced "reprimarization" during the sample period, meaning that economic activities are shifted away from manufacturing productions and back to primary commodities.

3.2.3 Stylized Facts between GVC Participation and Export Quality

Interested in analyzing the impact of an increase in GVC participation (in percentage points) on the change in export quality, I create a scatter plot in Figure 9 to illustrate the correlation between the natural log of ISIC industry-level *Export Quality* and the *GVC Participation Index* for all the country-industry pairs in the sample. It is worth noting that many country-industry pairs have very low *GVC Participation Index* values. Overall, there seems to be a positive correlation between these variables, suggesting that an increasing participation in GVC trade is associated with an improvement in industry-level export quality.

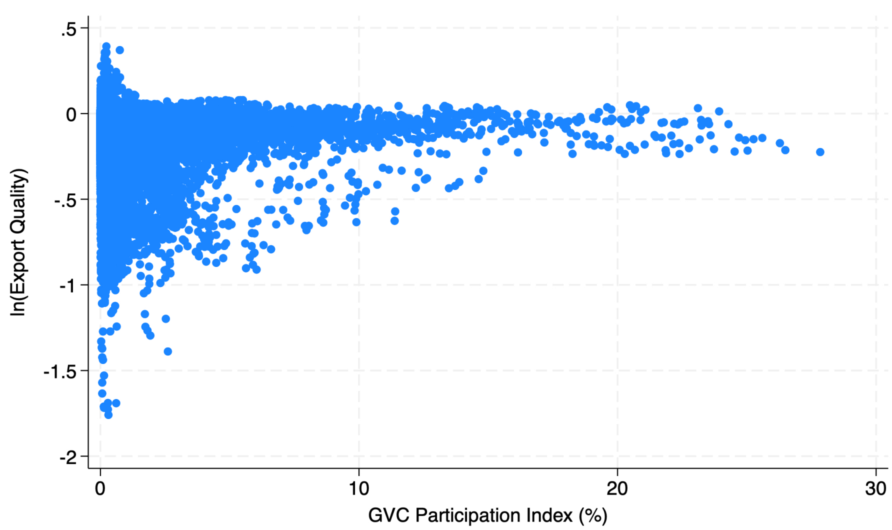


Figure 9. Scatter Plot between ln(Export Quality) and GVC Participation Index

4 Empirical Estimation

4.1 Baseline Specifications

To analyze the causal impact of GVC trade on export quality upgrading at the country-industry level, I estimate the following baseline specifications:

$$ln(EQ_{c,i,t}) = \beta_0 + \beta_1 ln(EQ_{c,i,t-1}) + \beta_2 GVCParticipation_{c,i,t-1} + \gamma X_{c,t-1} + u_{c,i} + \epsilon_{c,i,t}, \quad (14)$$

$$ln(EQ_{c,i,t}) = \beta_0 + \beta_1 ln(EQ_{c,i,t-1}) + \beta_2 ForwardGVC_{c,i,t-1} + \gamma X_{c,t-1} + u_{c,i} + \epsilon_{c,i,t}, \quad (15)$$

$$ln(EQ_{c,i,t}) = \beta_0 + \beta_1 ln(EQ_{c,i,t-1}) + \beta_2 BackwardGVC_{c,i,t-1} + \gamma X_{c,t-1} + u_{c,i} + \epsilon_{c,i,t}, \quad (16)$$

$$ln(EQ_{c,i,t}) = \beta_0 + \beta_1 ln(EQ_{c,i,t-1}) + \beta_2 ForwardGVC_{c,i,t-1} + \beta_3 BackwardGVC_{c,i,t-1} + \gamma X_{c,t-1} + u_{c,i} + \epsilon_{c,i,t}, \quad (17)$$

where c refers to country, i refers to the unique industries based on the 2-digit ISIC Rev. 4 classification, and t is year. EQ refers to export quality. $GVCParticipation_{c,i,t}$ is calculated as $(ForwardGVC_{c,i,t} + BackwardGVC_{c,i,t})$. X refers to a vector of regressors which potentially impact export quality with a delayed effect: GDP per capita; human capital; foreign direct investment net inflows as a share of GDP; investment (a.k.a. gross capital formation) as a share of GDP; institutional quality; and capital stock at constant prices. $u_{c,i}$ is the unobserved country-industry fixed effect, and $\epsilon_{c,i,t}$ is the error term.

I assume that the natural log of export quality in the current period is a function of the natural log of export quality and regressors with a 1-year lag. It is reasonable to assume that export quality is path-dependent: Export quality should not change significantly in the short-run; the best indicator of export quality in the current period is the value in the previous period. In the baseline analyses, equation (14) examines the impact of *GVC Participation Index* on export quality. I estimate equation (15) and (16) to isolate the effect of *Forward* or *Backward GVC Participation*. In equation (17), I include both *Forward* and *Backward GVC Participation* in the specification to examine the robustness of these coefficient estimates compared to those in (15) and (16). I hypothesize that both an increase in *Forward GVC Participation* and in *Backward GVC Participation* can have a positive effect on export quality upgrading. In terms of the forward GVC linkages, country-industry pairs which increase their domestic value-added content embodied in foreign exports as a share of the source country's total exports can potentially facilitate quality upgrading through channels such as learning-by-doing. A suitable example can be countries which have achieved economic growths through export-led development strategies: As countries and industries devote resources into producing and exporting goods themselves, they become self-sufficient and reduce their dependence on countries from which those goods were previously imported. Over time, trainings and practices through the production process enable countries and sectors to improve their export quality. In terms of the backward GVC linkages, countries and sectors which import a higher share of foreign value-added as a percentage of the recipient country's total exports may facilitate export upgrading through the positive technological spillovers embodied in the imported intermediates. Countries and sectors can utilize and build upon the imported technological components, especially if they are not capable of manufacturing the intermediates due to productive capacity or financial constraints.

4.2 Empirical Strategy

As previously discussed, drawing inference between GVC participation and economic upgrading can be challenging, due to sources of endogeneities such as reverse causality, omitted variable bias, and dynamic endogeneity. Endogeneity bias can result in inconsistent coefficient estimates and unreliable inferences. As illustrated in Nickell (1981), assume that a first-order autoregressive model has the following functional form:

$$y_{i,t} = \beta + \rho y_{i,t-1} + \sum_j \beta_j x_{i,j,t} + f_i + \epsilon_{i,t}, \tag{18}$$

where cross-sectional units $i = 1, 2, \ldots, N$; time periods $t = 1, 2, \ldots, T$; f_i are fixed effects; $\epsilon_{i,t}$ represents the idiosyncratic shocks with $IN(0, \sigma_\epsilon^2)$; and $|\rho| < 1$. Let E_i represent the expectation of a random variable taken over the individuals for a fixed time period, then $E(\epsilon_{i,t}) = 0$, and assume that $E(\epsilon_{i,t} f_i) = 0$. To eliminate the fixed effects f_i, a demeaning process can be performed on equation (18), such that the time mean is subtracted from equation (18) itself. It is apparent that $y_{i,t-1}$ and the error term $\epsilon_{i,t}$ are still correlated after the within-group transformation, which causes the coefficient estimate on the lagged dependent variable to be biased. Additionally, Nickell shows that the bias cannot be resolved by increasing the size of N: The inconsistency of the coefficient estimates on the lagged dependent variable $\hat{\rho}$ is approximately $\frac{1}{T}$ as $N \rightarrow \infty$, which can be sizable if T is small. If the true coefficient estimate ρ is positive, the bias will be negative, suggesting that the persistence of the dependent variable will be underestimated. Furthermore, introducing additional exogenous variables does not remove the dynamic endogeneity bias.

To properly examine the causal impact of participating in GVC trade on export quality upgrading, I employ two-step system Generalized Method of Moments (GMM), a DPD estimator based on the works of Anderson and Hsiao (1981, 1982), Hansen (1982), Holtz-Eakin et al. (1988), Arellano and Bond (1991), Arellano and Bover (1995), and Blundell and Bond (1998). GMM is a semi-parametric estimator which exploits information from the general form of population moment conditions without making extreme assumptions about the underlying data-generating process. According to Kripfganz (2019), when the error term $\epsilon_{i,t}$ is heteroskedastic, the one-step GMM estimator remains consistent under heteroskedasticity but is no longer efficient. The two-step estimator uses an optimal weighting matrix or its cluster-robust analogue, which creates efficient estimates. Since the modified Wald test suggests that heteroskedasticity is present in the residuals, I use the two-step estimator to increase efficiency. I use the system-GMM estimator rather than difference-GMM, as Blundell and Bond (1998) show that the latter could generate biased estimates when the sample period is short. System-GMM instruments the differenced variables which are not strictly exogenous with suitable lags in levels, and variables in levels are instrumented with suitable lags of their own first differences.

The two-step system-GMM estimator is a suitable technique which takes into account the dynamic model specification and deals with different sources of endogeneity, according to Roodman (2009), Wintoki and Netter (2012), and Ullah et al. (2018). First, by using lagged values of all regressors, I make the assumption that the GVC indicators and the controlled variables impact export quality with a one-year delay. To some extent, this addresses the concern of reverse causality, such that an improvement in export quality is a precursor for participating in GVC trade. Second, I instrument the lagged dependent variable and any other potentially endogenous control variables with "internal instruments" which are considered to be uncorrelated with the country-industry fixed effects (rather than "external instruments" in the case of two-stage least squares estimator).

Consistent with the GMM model assumptions, I make the following assumptions about the data. First, the estimated regressions include arbitrarily distributed individual-level fixed effects. This implies that there is unobserved heterogeneity at the country-industry level which varies over time and can be correlated with the regressors $x_{i,t-j}$. By construction, it is correlated with the lagged dependent variables $y_{i,t-j}$. Second, the idiosyncratic error term $\epsilon_{i,t}$ exhibits heteroskedasticity and autocorrelation within country-industry pairs but are uncorrelated across them (serially uncorrelated). Third, I assume that the regressors in the model can be endogenous, weakly exogenous/predetermined,[12] or strictly exogenous. Last, I assume that strong external instruments are not available within the immediate dataset. Instead, I rely on the internal instruments, which are lagged dependent and independent variables already existing in the dataset. Under certain sufficient conditions, the GMM estimator is efficient, consistent, and asymptotically normally distributed.

5 Empirical Results

5.1 Results from Baseline Specifications

To examine the causal impact of participating in GVC trade on export quality, I run four baseline specifications detailed in equation (14) to (17) using two-step system-GMM, with the regression results shown in Table 2.

Several post-estimation specification tests are performed. First, according to Arellano and Bond (1991), if the idiosyncratic error term $\epsilon_{i,t}$ is serially uncorrelated, the first-differenced residuals $\Delta\epsilon_{i,t}$ should exhibit first-order serial correlation but no higher-order serial correlation. The Arellano-Bond test for AR(1) detects the presence of first-order autocorrelation in the differenced errors. A probability of AR(1) less than 0.05 suggests that the null hypothesis of no first-order autocorrelation is rejected at 5% significance level. The test for AR(2) tests for the null hypothesis of no second-order autocorrelation. Therefore, the Arellano-Bond test should reject the null hypothesis of no first-order serial correlation in first differences (AR(1) test) but should not reject the null hypothesis of no higher-order serial correlation in first differences (AR(2) test). Second, the Hansen Overidentification Test is performed after two-step estimation with an optimal weighting matrix to determine the validity of overidentifying restrictions in the GMM model. In overidentified models, the number of instruments L is greater than the number of endogenous regressors K. The validity of $(L - K)$ overidentifying restriction is tested, with the null hypothesis that the overidentifying restrictions are valid. A probability greater than 0.05 in the Hansen Overidentification Test suggests that I fail to reject the null hypothesis at the 5% significance level. Third, two Difference-in-Hansen Tests are performed as a test of exogeneity for a subset of instruments. The "Difference-in-Hansen: Hansen test excluding group" reports the Hansen test for the first-differenced model. The null

[12] Predetermined variables are variables determined prior to the current period. This assumes that the error term in the current period is uncorrelated with past and contemporaneous values of the predetermined variable but may be correlated with future values. A strictly exogenous variable, on the other hand, requires that there is no correlation with previous, current, and future shocks.

hypothesis is that the model is dynamic complete, indicating the validity of the level instruments. "Difference-in-Hansen: Difference" tests for the mean stationarity condition required for the validity of the level instruments, with the null hypothesis that the level instruments are exogenous. Probabilities greater than 0.05 in Difference-in-Hansen tests suggest that I fail to reject the hypothesis that the instruments are valid. Last, it is worth noting that the specifications likely do not suffer from the issue of "too many instruments". (Roodman, 2009) According to Andersen and Sørensen (1996) and Bowsher (2002), too many instruments can weaken the Hansen test to the extent that it generates overly high p-values which are equal or close to 1. As an arbitrary rule of thumb, Roodman (2009) suggests that the number of instruments should be much less than the number of individual units. In my specifications, the number of country-industry units (1,631) tremendously outnumbers the number of instruments, which satisfies the requirement.

Several patterns can be observed from the dynamic model baseline regression results in Table 2. First, export quality is highly persistent across specifications: The coefficient on the natural log of the lagged value of export quality is statistically significant at the 1% level. Yet, the magnitude of persistence varies between 0.3729 and 0.6149, suggesting that specifications which do not separately include *Forward GVC Participation* as a regressor are subject to omitted variable bias, making the coefficient on the lagged dependent variable much larger. Second, baseline regression results support my hypothesis that increasing GVC participation leads to export quality upgrading one period ahead. In column (1), a one percentage point increase in *GVC Participation Index* improves export quality in the next period by $(e^{0.0019} - 1) =$ 0.19 percent, which is statistically significant at the 5% level. In column (2), the impact of forward GVC linkages is more pronounced: A one percentage point increase in *Forward GVC Participation* increases the export quality one period ahead by 0.54 percent, while column (3) shows that the effect of a one percentage point increase in *Backward GVC Participation* is 0.18 percent, significant at the 10% level. However, when both *Forward* and *Backward GVC Participation* are included in column (4), the impact of forward linkages rises to 0.64 percent, yet that of backward linkages is no longer statistically different from zero. This further suggests that omitting *Forward GVC Participation* as a separate variable results in omitted variable bias. Once it is included, the role of backward GVC linkage is insignificant, which indicates that column (3) is misspecified. Third, it is worth noting that the estimated effects of GVC indicators on export quality upgrading are small in terms of magnitude, despite statistical significance. However, the size of the impact estimated is larger than that in the existing literature. For instance, Ndubuisi and Owusu (2021) find that a one percentage point increase in GVC participation increases their measure of export quality by between 0.01 and 0.14 percent.

Table 2. The Impact of GVC Participation on Export Quality

Dependent Variable: Ln(EQ)	(1)	(2)	(3)	(4)
1-Year Lag of Ln(EQ)	0.6106***	0.4136***	0.6149***	0.3729**
	(0.0747)	(0.0450)	(0.0766)	(0.1673)
1-Year Lag of GVC Participation Index (%)	0.0019**			
	(0.0008)			
1-Year Lag of Forward GVC Participation (%)		0.0054**		0.0064*
		(0.0020)		(0.0035)
1-Year Lag of Backward GVC Participation (%)			0.0018*	-0.0013
			(0.0010)	(0.0019)
1-Year Lag of Ln(GDP Per Capita)	0.0389***	0.0442***	0.0369***	0.0514***
	(0.0085)	(0.0067)	(0.0087)	(0.0150)
1-Year Lag of Ln(Human Capital)	-0.0018	0.0410**	0.0034	0.0243
	(0.0156)	(0.0184)	(0.0159)	(0.0202)
1-Year Lag of FDI Net Inflows (% of GDP)	-0.0001	0.0000	-0.0001	-0.0001
	(0.0001)	(0.0000)	(0.0001)	(0.0001)
1-Year Lag of Investment (% of GDP)	0.0004**	0.0005**	0.0004*	0.0001
	(0.0002)	(0.0002)	(0.0002)	(0.0004)
1-Year Lag of Institutional Quality	0.0000	-0.0000	-0.0000	-0.0006
	(0.0001)	(0.0001)	(0.0001)	(0.0004)
1-Year Lag of Ln(Capital Stock)	-0.0054*	-0.0069**	-0.0049*	-0.0048
	(0.0029)	(0.0032)	(0.0029)	(0.0034)
Constant	-0.3652***	-0.4674***	-0.3566***	-0.5427***
	(0.0883)	(0.0663)	(0.0892)	(0.1880)
Observations	29,013	29,013	29,013	29,013
Number of Country-Industry Units	1,631	1,631	1,631	1,631
Arellano-Bond Test for AR(1)	0	0	0	0.001
Arellano-Bond Test for AR(2)	0.633	0.804	0.626	0.761
Hansen Test of Overid. Restrictions	0.099	0.183	0.074	0.105
Diff-in-Hansen: Hansen Test Excluding Group	0.086	0.120	0.152	0.123
Diff-in-Hansen: Difference (H_0: Exogenous)	0.337	0.424	0.116	0.249
Number of Instruments	51	43	51	55

Notes: Results are generated via two-step system-GMM. Heteroskedasticity-robust and autocorrelation-robust standard errors are in parentheses. Coefficients for the time fixed effects are omitted for brevity. $^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$.

Regarding the effect of the control variables, the impact of a one percentage point increase in GDP per capita is significant at the 1% level, whose effect ranges from 3.97 percent (calculated by $(e^{0.0389} - 1)$) to 5.27 percent across specifications. An increase in the investment as a share of GDP has a positive impact on export quality in columns (1) to (3), but its effect is not significant in column (4). Contrary to my hypothesis that increasing capital stock should improve export quality, results show that increasing the amount of capital stock by one percentage point links to a decrease in export quality in the first three specifications, and the effect is no longer significant in column (4). The anomalous finding may be due to the fact that the capital stock variable may be subject to data availability and measurement error issues. For instance, data on capital stock for most non-OECD countries are not properly measured.

The statistics for the post-estimation specification tests and the number of instruments suggest that my specifications satisfy the Arellano-Bond Test, the Hansen Overidentification Test, and the Difference-in-Hansen Tests. In the analyses to follow, I only report the regression specifications in equation (14) and (17), which correspond to baseline columns (1) and (4).

5.2 Heterogeneous Effects Across Countries

5.2.1 Interaction Effects of GVC Trade and Export Quality

It is reasonable to assume that participating in GVC trade does not have a universal effect on all countries. One might assume that sectors with higher levels of export quality benefit more from increasing global trade integration due to existing advantages, compared to those with lower export qualities. Conversely, some literature has suggested that increasing GVC participation leads to a "catch-up effect" of economic outcomes. For instance, Pahl and Timmer (2020) find that GVC participation has a stronger impact on the growth of formal manufacturing labor productivity for sectors with lower initial levels of labor productivity. To examine whether the impact of GVC trade hinges on the level of export quality, I test the following specifications:

$$\begin{aligned} ln(EQ_{c,i,t}) = \beta_0 + \beta_1 ln(EQ_{c,i,t-1}) + \beta_2 GVCParticipation_{c,i,t-1} + \beta_3 (ln(EQ_{c,i,t-1}) \\ * GVCParticipation_{c,i,t-1}) + \gamma X_{c,t-1} + u_{c,i} + \epsilon_{c,i,t}, \quad (19) \end{aligned}$$

$$\begin{aligned} ln(EQ_{c,i,t}) = \beta_0 + \beta_1 ln(EQ_{c,i,t-1}) + \beta_2 ForwardGVC_{c,i,t-1} + \beta_3 BackwardGVC_{c,i,t-1} \\ + \beta_4 (ForwardGVC_{c,i,t-1} * ln(EQ_{c,i,t-1})) + \beta_5 (BackwardGVC_{c,i,t-1} * ln(EQ_{c,i,t-1})) + \\ \gamma X_{c,t-1} + u_{c,i} + \epsilon_{c,i,t}, \quad (20) \end{aligned}$$

The main coefficients of interest in equation (19) are β_2 and β_3. β_2 is the effect of GVC participation on export quality when *ln(Export Quality)* equals zero. $\beta_3 < 0$ would suggest a catch-up effect: The impact of participating in GVC trade is higher the lower the existing export quality is. While $\beta_3 > 0$ would suggest an absence of such effect: Country-industry pairs with higher existing export qualities will benefit more from increasing GVC trade. For equation (20), the main coefficients of interest are β_2, β_3, β_4, and β_5.

Table 3. Interaction Effects of GVC Indicators and Export Quality

Dependent Variable: Ln(EQ)	(1)	(2)
1-Year Lag of Ln(EQ)	0.3731***	0.3853***
	(0.0475)	(0.0477)
1-Year Lag of GVC Participation Index (%)	0.0090***	
	(0.0018)	
1-Year Lag of Forward GVC Participation (%)		0.0070***
		(0.0020)
1-Year Lag of Backward GVC Participation (%)		0.0110***
		(0.0029)
1-Year Lag of (Ln(EQ) x GVC Participation Index)	0.0642***	
	(0.0171)	
1-Year Lag of (Ln(EQ) x Forward GVC Participation)		0.0397**
		(0.0177)
1-Year Lag of (Ln(EQ) x Backward GVC Participation)		0.0783***
		(0.0240)
1-Year Lag of Ln(GDP Per Capita)	0.0401***	0.0420***
	(0.0066)	(0.0064)
1-Year lag of Ln(Human Capital)	0.0451***	0.0336**
	(0.0174)	(0.0164)
1-Year Lag of FDI Net Inflows (% of GDP)	0.0000	0.0000
	(0.0000)	(0.0000)
1-Year Lag of Investment (% of GDP)	0.0004*	0.0005**
	(0.0002)	(0.0002)
1-Year Lag of Institutional Quality	0.0000	0.0000
	(0.0001)	(0.0001)
1-Year Lag of Ln(Capital Stock)	-0.0079**	-0.0078**
	(0.0033)	(0.0033)
Constant	-0.4194***	-0.4281***
	(0.0654)	(0.0648)
Observations	29,013	29,013
Number of Country-Industry Units	1,631	1,631
Arellano-Bond test for AR(1)	0	0
Arellano-Bond test for AR(2)	0.741	0.796
Hansen Test of Overid. Restrictions	0.609	0.301
Diff-in-Hansen: Hansen Test Excluding Group	0.456	0.094
Diff-in-Hansen: Difference (H_0: Exogenous)	0.641	0.765
Number of Instruments	46	52

Notes: Results are generated via two-step system-GMM. Heteroskedasticity-robust and autocorrelation-robust standard errors are in parentheses. Time fixed effects are omitted for brevity. $^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$.

Table 3 reports the regression results for the interaction effects of lagged values of GVC indicators and export quality. Column (1) shows that the interaction effect is positive: The positive impact of participating in GVC trade is greater the higher the existing country-industry level export quality is. The same is true for the coefficients of the interaction terms in column (2), suggesting that the positive effects of increasing either forward or backward linkages on export quality are higher in country-industry units with higher existing export qualities.

To visualize the non-linear effect, I plot the average marginal effects of the lagged *GVC Participation Index* on different values of *ln(Export Quality)* with 95% confidence intervals in Figure 10. As the value of *ln(Export Quality)* improves, the average marginal effect of lagged *GVC Participation Index* switches signs, shifting from negative and statistically significant to zero, then to positive and statistically significant. Intuitively, increasing the level of GVC participation in country-industry pairs with existing high levels of export quality would result in a further improvement of export quality one period from now, while increasing GVC participation in lower values of export quality links to a further decline of export quality one period ahead. Therefore, the empirical evidence does not support the existence of a catch-up effect in the sample.

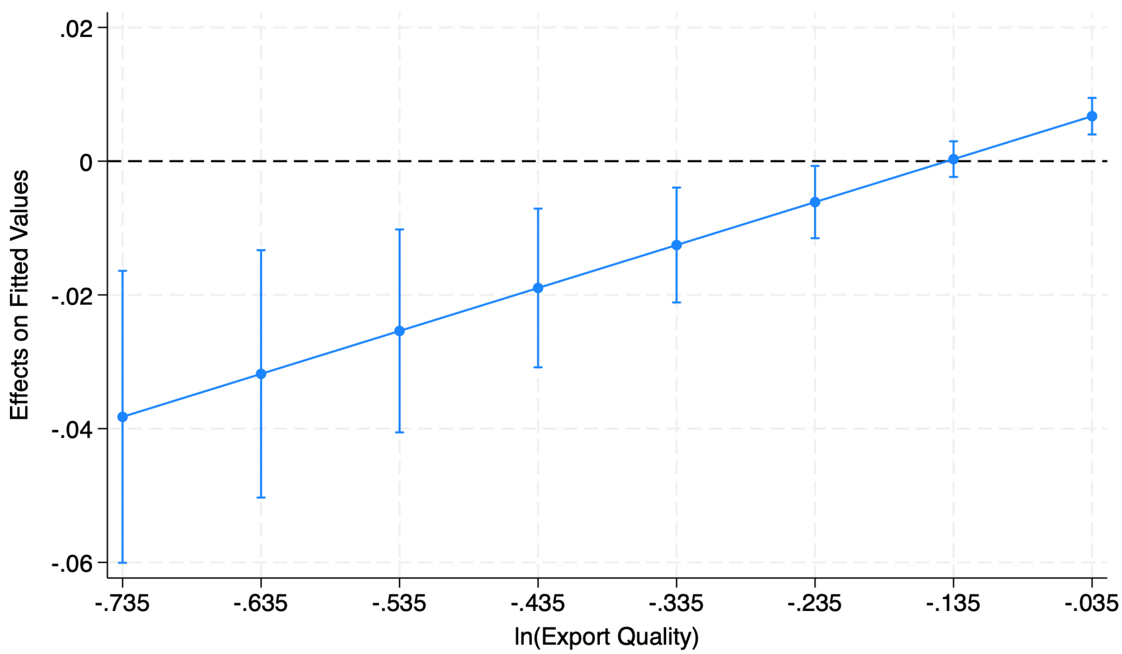


Figure 10. Average Marginal Effects of Lagged GVC Participation Index with 95% CIs

Furthermore, an increase in GDP per capita, human capital, and investment as a share of GDP each has a delayed positive and significant impact on export quality, while an increase in the level of capital stock has the opposite effect.

5.2.2 Effects of GVC Trade on Export Quality by Countries' Development Status

Next, I examine the heterogenous effect of GVC trade on export quality by countries' development status. Using the IMF World Economic Outlook (WEO) classification, I group the 61 countries in the sample into "advanced economies" and "emerging market and developing economies", of which 32 are advanced economies and 29 are EMDEs. Regression results in Table 4 show that the impact of a one percentage point increase in *GVC Participation Index* is positive and significant for both advanced and EMDE countries, with the effect being smaller for advanced economies (0.12 percent) and nearly tripled for EMDEs (0.34 percent). Consistent with findings that forward linkages are propelling the positive impact, a one percentage point increase in forward GVC linkages improves the export quality by 0.30 percent for advanced economies and 0.68 percent for EMDEs. Furthermore, no other regressors are estimated to increase export quality in the advanced economies subsample. In comparison, an increase in GDP per capita and investment as a share of GDP significantly raise export quality among EMDEs. As a robustness check, I group the countries into lower-middle, upper-middle, and high-income countries based on the World Bank Country and Lending Groups income classification. Subsample regression results reported in Table C1 suggest that the positive effects of GVC trade on export quality upgrading among EMDEs are driven by upper-middle-income economies.

5.2.3 Effects of GVC Trade on Export Quality for Countries with Improved Income Status

To further investigate the relationship between participating in GVC trade and countries' development trajectories, I repeat the exercise using a subset of countries which have transitioned into a higher income level in 2014. For each country, I compare its income status based on the World Bank Group Country Classifications in 1995 versus in 2014. I code a country whose value of "income improvement" is equal to 1 if it has successfully advanced to any higher income level over 20 years, and 0 otherwise.

Table 4. Effects of GVC Trade on Export Quality by Countries' Development Status

Dependent Variable: Ln(EQ)	(1) Advanced Economies	(2) Advanced Economies	(3) EMDEs	(4) EMDEs
1-Year Lag of Ln(EQ)	0.8682***	0.8121***	0.4024***	0.3984***
	(0.1087)	(0.0939)	(0.0477)	(0.0464)
1-Year Lag of GVC Participation Index (%)	0.0012*		0.0034*	
	(0.0006)		(0.0017)	
1-Year Lag of Forward GVC Participation (%)		0.0030*		0.0068***
		(0.0018)		(0.0023)
1-Year Lag of Backward GVC Participation (%)		0.0010		-0.0006
		(0.0008)		(0.0025)
1-Year Lag of Ln(GDP Per Capita)	0.0096	0.0129	0.0418***	0.0392***
	(0.0086)	(0.0080)	(0.0100)	(0.0097)
1-Year lag of Ln(Human Capital)	-0.0229	-0.0227	0.0268	0.0327
	(0.0226)	(0.0227)	(0.0245)	(0.0243)
1-Year Lag of FDI Net Inflows (% of GDP)	-0.0001	-0.0001	0.0001	0.0001
	(0.0001)	(0.0001)	(0.0001)	(0.0001)
1-Year Lag of Investment (% of GDP)	-0.0004	-0.0006*	0.0006**	0.0005*
	(0.0003)	(0.0003)	(0.0003)	(0.0003)
1-Year Lag of Institutional Quality	-0.0002	-0.0011	0	0
	(0.0032)	(0.0031)	(0.0001)	(0.0001)
1-Year Lag of Ln(Capital Stock)	-0.0020	-0.0020	-0.0060	-0.0078*
	(0.0025)	(0.0024)	(0.0045)	(0.0046)
Constant	-0.0412	-0.0732	-0.4454***	-0.4040***
	(0.0912)	(0.0839)	(0.1040)	(0.1031)
Observations	15,562	15,562	13,451	13,451
Number of Country-Industry Units	862	862	769	769
Arellano-Bond test for AR(1)	0	0	0	0
Arellano-Bond test for AR(2)	0.878	0.859	0.968	0.977
Hansen Test of Overid. Restrictions	0.264	0.254	0.242	0.209
Diff-in-Hansen: Hansen Test Excluding Group	0.220	0.263	0.064	0.104
Diff-in-Hansen: Difference (H_0: Exogenous)	0.395	0.324	0.928	0.656
Number of Instruments	43	46	51	55

Notes: Results are generated via two-step system-GMM. Classification of countries' development status is based on the IMF World Economic Outlook Database. In this sample, 32 countries are advanced economies and 29 countries are EMDEs. Heteroskedasticity-robust and autocorrelation-robust standard errors are in parentheses. Time fixed effects are omitted for brevity. $^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$.

Regression results in Table 5 supplement my findings in Table 4: Among the 28 countries which experienced an improved income status during the sample period, increasing GVC integration improves export quality at the 5% significance level. Specifically, among countries which have transitioned to a higher income status within the 20 years, a one percentage point increase in forward GVC linkages results in a 0.52 percent increase in export quality. This magnitude is comparable (though slightly smaller) to the coefficient estimates of *Forward GVC Participation* in my full sample and among the subsample of EMDEs. This indicates that since the 1990s, middle-income countries that advanced to a higher income bracket have reaped the benefits of GVC trade in terms of export quality. These findings highlight the importance of increasing GVC integration in countries' development paths.

Table 5. Subsample Analyses of Effects of GVC Trade on Export Quality for Countries with Improved Income Status, 1995-2014

Dependent Variable: Ln(EQ)	(1)	(2)
1-Year Lag of Ln(EQ)	0.4503***	0.4511***
	(0.0633)	(0.0624)
1-Year Lag of GVC Participation Index (%)	0.0028**	
	(0.0012)	
1-Year Lag of Forward GVC Participation (%)		0.0052**
		(0.0022)
1-Year Lag of Backward GVC Participation (%)		0.0021
		(0.0013)
1-Year Lag of Ln(GDP Per Capita)	0.0403***	0.0401***
	(0.0102)	(0.0104)
1-Year lag of Ln(Human Capital)	0.0405	0.0378
	(0.0267)	(0.0269)
1-Year Lag of FDI Net Inflows (% of GDP)	0.0001	0.0001
	(0.0001)	(0.0001)
1-Year Lag of Investment (% of GDP)	0.0008***	0.0008***
	(0.0003)	(0.0003)
1-Year Lag of Institutional Quality	0.0001	0.0001
	(0.0001)	(0.0001)
1-Year Lag of Ln(Capital Stock)	-0.0085*	-0.0074
	(0.0051)	(0.0050)
Constant	-0.4128***	-0.4240***
	(0.1180)	(0.1208)
Observations	12,941	12,941
Number of Country-Industry Units	743	743
Arellano-Bond test for AR(1)	0	0
Arellano-Bond test for AR(2)	0.542	0.541
Hansen Test of Overid. Restrictions	0.130	0.063
Diff-in-Hansen: Hansen Test Excluding Group	0.198	0.175
Diff-in-Hansen: Difference (H_0: Exogenous)	0.183	0.086
Number of Instruments	43	46

Notes: Results are generated via two-step system-GMM. Countries with improved income status are defined as countries whose income status in 2014 are higher than their income status in 1995, based on the World Bank Country and Lending Groups income classification in 1995 and 2014. Heteroskedasticity-robust and autocorrelation-robust standard errors are in parentheses. Time fixed effects are omitted for brevity. $^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$.

5.2.4 Effects of GVC Trade on Export Quality among East Asia and Pacific Countries

Furthermore, I examine the effects for countries located in East Asia and Pacific in the sample. It is worth noting that this region's participation in GVC trade likely differs from the rest of the world. The region has experienced tremendous economic growths between the 1990s and mid-2010s, driven largely by the "Four Asian Tigers" (Hong Kong, Taiwan, Singapore, and South Korea), the economic reforms in China, and the rise of Vietnam. These economies implemented export-oriented policies to expedite the industrialization process by enacting policies including but not limited to tariff reductions, government subsidies of select industries, consolidating state-owned entities to develop manufacturing sectors, and attracting FDI. In particular, China's open-door policy facilitated technological innovation, experimentation, and free-trade practices in special economic zones and industry clusters designated in coastal areas. China's accession to the WTO in 2001 further consolidated China's role as a major player in global trade. Therefore, one might expect that countries in East Asia and Pacific have engaged heavily in both forward and backward GVC linkages.

Table 6 reports the regression results for this subsample. Contrary to my hypothesis that both forward and backward GVC linkages would induce a positive impact, column (2) shows that both GVC indicators impact export quality, but in opposite directions. A one percentage point increase in forward GVC linkages increases export quality by 1.37 percent, which is larger than the magnitude in other country samples considered. However, a one percentage point increase in backward GVC linkages decreases export quality by 0.46 percent, suggesting that export-led policies have resulted in upward changes, while an increasing reliance on imported intermediates reverses the impact by one-third. The negative coefficient on backward GVC linkages can be potentially driven by countries which perform labor-intensive economic activities, such as low-skilled manufacturing and assembly operations. In this case, advanced economies offshore labor-intensive tasks to these countries to take advantage of lower wages. Despite being more integrated into the global economy, the nature of these economic activities involves minimal value-added (due to low wages) and little immediate prospect for quality upgrading in these sectors. In addition to the robust and positive effect of GDP per capita, a one percentage point increase in the share of FDI net inflows has a statistically significant impact, enhancing export quality by between 0.11 percent and 0.13 percent.

Table 6. Effects of GVC Trade on Export Quality among East Asia and Pacific Countries

Dependent Variable: Ln(EQ)	(1)	(2)
1-Year Lag of Ln(EQ)	0.6218***	0.5845***
	(0.1348)	(0.1308)
1-Year Lag of GVC Participation Index (%)	-0.0010	
	(0.0019)	
1-Year Lag of Forward GVC Participation (%)		0.0137***
		(0.0046)
1-Year Lag of Backward GVC Participation (%)		-0.0046**
		(0.0020)
1-Year Lag of Ln(GDP Per Capita)	0.0363**	0.0344***
	(0.0151)	(0.0125)
1-Year lag of Ln(Human Capital)	-0.0080	0.0010
	(0.0451)	(0.0415)
1-Year Lag of FDI Net Inflows (% of GDP)	0.0011*	0.0013**
	(0.0006)	(0.0006)
1-Year Lag of Investment (% of GDP)	0.0004	0.0005
	(0.0005)	(0.0005)
1-Year Lag of Institutional Quality	-0.0009	-0.0002
	(0.0036)	(0.0034)
1-Year Lag of Ln(Capital Stock)	0.0053	0.0061
	(0.0055)	(0.0051)
Constant	-0.4753**	-0.4973***
	(0.1873)	(0.1686)
Observations	6,181	6,181
Number of Country-Industry Units	370	370
Arellano-Bond test for AR(1)	0	0
Arellano-Bond test for AR(2)	0.069	0.082
Hansen Test of Overid. Restrictions	0.127	0.182
Diff-in-Hansen: Hansen Test Excluding Group	0.328	0.744
Diff-in-Hansen: Difference (H_0: Exogenous)	0.064	0.100
Number of Instruments	59	64

Notes: Results are generated via two-step system-GMM. East Asia and Pacific countries are defined based on the World Bank country classifications by geographic regions. Heteroskedasticity-robust and autocorrelation-robust standard errors are in parentheses. Time fixed effects are omitted for brevity. $^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$.

5.3 Heterogeneous Effects Across Industries

5.3.1 Interaction Effects of GVC Trade and Manufacturing Industries

Motivated by the variations in GVC trade and export qualities among sectors in the stylized facts, I analyze the heterogeneous effects across industries in this section. One would argue that increasing GVC integration in the manufacturing sectors would improve export quality more, as manufacturing products are more differentiated and complex compared to sectors such as agriculture, forestry, hunting, fishing, and mining industries. The embedded technological contents in the manufacturing sectors may provide countries and industries with more opportunities to climb the quality ladder. On the contrary, commodities tend to be homogeneous in nature and less likely to be distinguishable among suppliers. Therefore, there is less variation in quality differences or potential for quality upgrading among these sectors.

Table 7 reports the regression results on the interaction effect of GVC participation and manufacturing industries. Several results are noteworthy. First, both specifications (1) and (2) show that an increase in GVC integration in the non-manufacturing industries correspond to a statistically significant decrease in export quality. Second, the coefficient on dummy variable *Manuf* is positive and significant. Third, the coefficient estimates on interaction terms in both specifications are positive and significant at the 5% level. Intuitively, compared to non-manufacturing sectors, the effect of a one percentage point increase in forward GVC linkages on export quality is positive in the manufacturing sectors. I therefore conclude that the positive impact of GVC trade on export quality upgrading is predominantly driven by the manufacturing industries.

5.3.2 Interaction Effects of GVC Trade and R&D Intensities

Following the discussion above, I explore whether the impact of GVC trade on export quality differs among industries of various R&D intensities. Though innovations take place in higher education and government-sponsored projects as well, the competitive nature among entrepreneurs ensures that industrial R&D plays a crucial role in the creation of increasingly sophisticated technologies and complex products. Therefore, I hypothesize that an interaction of GVC participation and sectoral R&D intensity should matter to export quality: Increasing GVC trade in sectors with low R&D intensities will reduce export quality, as these sectors put less emphasis on closing the knowledge gap between them and the quality leaders compared to sectors which actively dedicate resources to facilitate innovation.

Table 7. Interaction Effects of GVC Trade and Manufacturing Industries

	(1)	(2)
Dependent Variable: Ln(EQ)		
1-Year Lag of Ln(EQ)	0.4840***	0.4231***
	(0.0941)	(0.1200)
1-Year Lag of GVC Participation Index (%)	-0.0223**	
	(0.0098)	
1-Year Lag of Forward GVC Participation (%)		-0.1266*
		(0.0663)
1-Year Lag of Backward GVC Participation (%)		0.0087
		(0.0212)
Dummy Variable: Manufacturing Sector	0.0176***	0.0116*
	(0.0054)	(0.0068)
1-Year Lag of GVC Participation Index x Manuf	0.0230**	
	(0.0098)	
1-Year Lag of Forward GVC Participation x Manuf		0.1314**
		(0.0668)
1-Year Lag of Backward GVC Participation x Manuf		-0.0097
		(0.0212)
1-Year Lag of Ln(GDP Per Capita)	0.0498***	0.0437***
	(0.0109)	(0.0113)
1-Year lag of Ln(Human Capital)	-0.0164	0.0224
	(0.0185)	(0.0171)
1-Year Lag of FDI Net Inflows (% of GDP)	0.0001	0
	(0.0001)	(0.0001)
1-Year Lag of Investment (% of GDP)	0	0
	(0.0003)	(0.0003)
1-Year Lag of Institutional Quality	-0.0003	-0.0003
	(0.0005)	(0.0003)
1-Year Lag of Ln(Capital Stock)	-0.0059*	-0.0004
	(0.0030)	(0.0028)
Constant	-0.4659***	-0.5236***
	(0.1179)	(0.1417)
Observations	29,013	29,013
Number of Country-Industry Units	1,631	1,631
Arellano-Bond test for AR(1)	0	0
Arellano-Bond test for AR(2)	0.910	0.886
Hansen Test of Overid. Restrictions	0.418	0.380
Diff-in-Hansen: Hansen Test Excluding Group	0.608	0.373
Diff-in-Hansen: Difference (H_0: Exogenous)	0.176	0.431
Number of Instruments	65	86

Notes: Results are generated via two-step system-GMM. Manufacturing industries are based on the OECD TiVA (2021) industry classification at the ISIC Rev.4 level. Heteroskedasticity-robust and autocorrelation-robust standard errors are in parentheses. Time fixed effects are omitted for brevity. $^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$.

I reference Galindo-Rueda and Verger (2016), who use the 2011 *OECD ANBERD*[13] and *OECD STAN Databases* to create a measure for industry-level R&D intensity, defined as the ratio of R&D expenditure to value-added within an industry. Figure 11 illustrates the variations in sectoral R&D intensities across industries and countries. The weighted average of R&D intensities is highest in the air and spacecraft industry and lowest in the real estate industry. Within each industry, countries vary substantially in terms of R&D intensities.

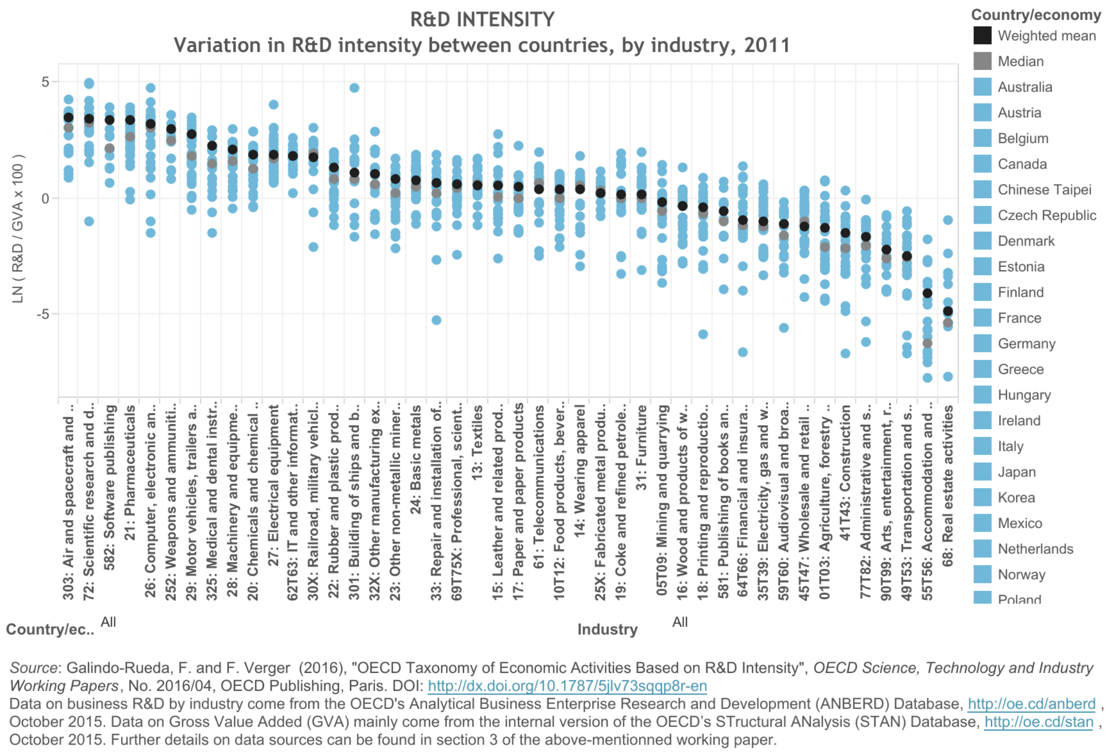


Figure 11. Variation in Sectoral R&D Intensity Between Countries, 2011

In Galindo-Rueda and Verger (2016), manufacturing and non-manufacturing activities are grouped into five categories based on R&D intensity: low, medium-low, medium, medium-high, and high. Considering that too many dummy variables will drastically increase the number of instruments in the GMM estimation and weaken the Hansen test statistic, I create a dummy variable *RnD_Low*, which equals 1 for industries categorized as low R&D intensities and 0 for the remaining four groups. Table 8 presents the results for the interaction effects between GVC indicators and low R&D intensities.

[13]The *ANBERD Database* includes most OECD countries and some partner countries, with industry classification at the ISIC level.

Table 8. Interaction Effects of GVC Trade and R&D Intensities

Dependent Variable: Ln(EQ)	(1)	(2)
1-Year Lag of Ln(EQ)	0.4126***	0.4143***
	(0.0478)	(0.0488)
1-Year Lag of GVC Participation Index (%)	0.0012	
	(0.0011)	
1-Year Lag of Forward GVC Participation (%)		0.0043**
		(0.0021)
1-Year Lag of Backward GVC Participation (%)		-0.0003
		(0.0017)
Dummy Variable: Low R&D Intensity	-0.0133**	-0.0059
	(0.0063)	(0.0073)
1-Year Lag of GVC Participation Index x Low R&D Intensity	-0.0214	
	(0.0223)	
1-Year Lag of Forward GVC Participation x Low R&D Intensity		-0.1668*
		(0.0871)
1-Year Lag of Backward GVC Participation x Low R&D Intensity		0.0183
		(0.0193)
1-Year Lag of Ln(GDP Per Capita)	0.0454***	0.0464***
	(0.0068)	(0.0069)
1-Year lag of Ln(Human Capital)	0.0387**	0.0346**
	(0.0180)	(0.0175)
1-Year Lag of FDI Net Inflows (% of GDP)	0	0
	0	0
1-Year Lag of Investment (% of GDP)	0.0004*	0.0005**
	(0.0002)	(0.0002)
1-Year Lag of Institutional Quality	0	0
	(0.0001)	(0.0001)
1-Year Lag of Ln(Capital Stock)	-0.0076**	-0.0067**
	(0.0032)	(0.0032)
Constant	-0.4585***	-0.4792***
	(0.0670)	(0.0683)
Observations	29,013	29,013
Number of Country-Industry Units	1,631	1,631
Arellano-Bond test for AR(1)	0	0
Arellano-Bond test for AR(2)	0.801	0.810
Hansen Test of Overid. Restrictions	0.097	0.072
Diff-in-Hansen: Hansen Test Excluding Group	0.055	0.056
Diff-in-Hansen: Difference (H_0: Exogenous)	0.395	0.397
Number of Instruments	47	53

Notes: Results are generated via two-step system-GMM. Sectoral R&D intensity is obtained from Galindo-Rueda and Verger (2016). Heteroskedasticity-robust and autocorrelation-robust standard errors are in parentheses. Time fixed effects are omitted for brevity. $^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$.

For industries whose R&D intensities are not low, increasing the forward linkages by one percentage point significantly increases the export quality by 0.43 percent. The coefficient on (*Forward GVC Participation* x *RnD_Low*) is negative and significant:

Compared to sectors not categorized as having low R&D intensities, an increase in forward GVC linkages in low-R&D intensity sectors will significantly decrease the sector's export quality at the 10% level. Consistent with my hypothesis, this suggests that compared to country-industry pairs which proactively advance their productive technologies through R&D, simply contributing to value-added contents in the low R&D intensity sectors actually widens the export quality gap between them and the quality frontier, as they are left further behind in the competition. For higher R&D intensity sectors, increasing GDP per capita, human capital, and share of investment also improves export quality.

5.3.3 Impact of Industry-Level Differentiated Products on Export Quality Upgrading

As a last exercise in this section, I explore whether the share of industry-level differentiated products affects the sectoral export quality, and why it is crucial to take it into account in the analysis. Differentiated products tend to be more diverse in terms of design, specification, and quality, which enable their producers to charge higher unit prices, of which my quality measure is based on. I hypothesize that increasing the share of sectoral differentiated products is a significant contributor to the improvement of export quality. To test my hypothesis, I utilize the SITC Rev.2 product classification by Rauch (1999), who groups internationally traded products into three categories: traded on an organized exchange, referenced priced, and differentiated products. The three categories reflect an increasing level of differentiation in this order. The Rauch classification is based on both a "conservative" and a "liberal" definition: The former assigns fewer products to the "traded on an organized exchange" and "referenced priced" categories, and more products to the "differentiated" category. The opposite is true for the "liberal" definition. Using the SITC-ISIC concordance I created, which maps SITC products to ISIC industries of different revisions, I merge the Rauch classification into the concordance, so that non-duplicated products at the SITC Rev.2 level are mapped to each industry at the ISIC Rev.4 level.

There are 985 distinct products overall. Table 9 shows the number of differentiated versus undifferentiated products based on each definition. 588 out of 985 products are considered as differentiated products (59.7 percent) based on the "conservative" definition, compared to 541 out of 985 products (54.9 percent) using the "liberal" definition. Following the "conservative" definition, I create a dummy variable *Differ-*

entiated, which equals 1 if a product is considered as differentiated and 0 otherwise. I calculate the sectoral share of differentiated products by dividing the number of differentiated products with the total number of products within each sector. Then, I include the variable *Share of Differentiated Products* as a regressor in the GMM estimation. Results are shown in Table 10.

Table 9. Number of Differentiated Products Using The Rauch Classification

Type of Product	Conservative Definition	Liberal Definition
(Traded on an Organized Exchange + Reference Priced)	397	444
Differentiated Product	588	541
Total	985	985

First, I observe positive, significant, and robust effects of forward GVC linkages and GDP per capita on export quality upgrading. Furthermore, consistent with my hypothesis, the variable *Share of Differentiated Products* is a positive and statistically significant predictor of export quality upgrading. A ten percentage points increase in the share of industry-level differentiated products will increase export quality by between 0.2 percent and 0.4 percent, which is statistically significant at the 1% level. The empirical results are closely related to the analysis and discussion regarding the manufacturing sectors. Since the majority of differentiated products are produced in the manufacturing sectors, a higher share of differentiated products in these sectors represents manufacturers' ability to distinguish their own products from those of competitors, possibly in terms of specification, technology, durability, usage, to list a few. Therefore, producers in the manufacturing sectors are more likely to charge higher unit values (which embody higher export qualities) on their products compared to commodity exporters.

Table 10. Impact of Industry-Level Differentiated Products on Export Quality Upgrading

Dependent Variable: Ln(EQ)	(1)	(2)
1-Year Lag of Ln(EQ)	0.6163***	0.3736***
	(0.0748)	(0.1400)
1-Year Lag of GVC Participation Index (%)	0.0023***	
	(0.0008)	
1-Year Lag of Forward GVC Participation (%)		0.0061**
		(0.0031)
1-Year Lag of Backward GVC Participation (%)		-0.0012
		(0.0017)
1-Year Lag of Ln(GDP Per Capita)	0.0378***	0.0488***
	(0.0084)	(0.0131)
1-Year lag of Ln(Human Capital)	-0.0021	0.0236
	(0.0154)	(0.0182)
1-Year Lag of FDI Net Inflows (% of GDP)	-0.0001	0
	(0.0001)	(0.0001)
1-Year Lag of Investment (% of GDP)	0.0004*	0.0001
	(0.0002)	(0.0003)
1-Year Lag of Institutional Quality	0	-0.0003
	(0.0001)	(0.0004)
1-Year Lag of Ln(Capital Stock)	-0.0051*	-0.0028
	(0.0029)	(0.0029)
Share of Differentiated Products	0.0002***	0.0004***
	(0.0001)	(0.0001)
Constant	-0.3734***	-0.5711***
	(0.0902)	(0.1681)
Observations	29,013	29,013
Number of Country-Industry Units	1,631	1,631
Arellano-Bond test for AR(1)	0	0.0001
Arellano-Bond test for AR(2)	0.620	0.736
Hansen Test of Overid. Restrictions	0.088	0.162
Diff-in-Hansen: Hansen Test Excluding Group	0.088	0.177
Diff-in-Hansen: Difference (H_0: Exogenous)	0.284	0.301
Number of Instruments	52	65

Notes: Results are generated via two-step system-GMM. The share of differentiated products is calculated using the conservative definition of the Rauch classification. Heteroskedasticity-robust and autocorrelation-robust standard errors are in parentheses. Time fixed effects are omitted for brevity. $^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$.

5.4 Heterogenous Effects across Countries' and Industries' Positions in GVCs, Measured by Upstreamness

The existing theoretical and empirical literature on GVC trade highlights the importance of measuring countries' and sectors' positions in the value chains. Fally (2011) proposes a measure of upstreamness, which estimates the extent of vertical fragmentation of production chains across firms, based on the assumption that sectors selling a disproportionate share of their output to the relatively upstream sectors are likely in relatively upstream positions themselves. Antràs et al. (2012) propose that the fragmentation of production across geographical boundaries has crucial implications for trade patterns. The authors present two approaches to building a measure of sectoral upstreamness, which appear distinct but are in fact equivalent. Using the 2002 U.S. Benchmark Input-Output (I-O) Tables , they find that the U.S. industries vary considerably in their average production line position, and that the average industry enters into production processes about one stage before final use. Borin and Mancini (2019) point out that considering the position of a country or sector within the production chain is helpful in analyzing the international propagation of macroeconomic shocks. In addition, trade policies may produce heterogeneous impacts on different trading members, depending on the extent of their involvement in GVCs.

Therefore, a natural question to ask is: Does the impact of participating in GVCs on export quality upgrading vary based on a country's and industry's position within the production chain? To address this question, I construct a country-industry-level measure of upstreamness by adopting the methodologies presented in Antràs et al. (2012) and using 2014 OECD Inter-Country Input-Output (ICIO) tables released in 2023. Recorded annually, ICIO tables provide a globally balanced view of inter-country inter-industry flows of intermediate demand and final goods and services, from which the TiVA indicators are derived. The ICIO 2023 edition provides data coverage on 76 countries and 45 industries at the ISIC Revision 4 classification. Appendix D details the conceptual framework of the ICIO models and the upstreamness measure.

Using the methodology detailed in Appendix D, the generated Upstreamness column vector measures the position in the value chain for (76 countries * 45 industries – 25 country-industry pairs) = 3395 country-industry pairs. Consistent with the existing empirical evidence, I find that countries and industries vary substantially in terms of the position of their average production line. The country-industry measure of upstreamness ranges from a minimum of 1 (where all output only goes to final uses) to a maximum of 5.5276 (mining support service activities in Kazakhstan, whose output is more than 4.5 stages from final uses). The mean value across 3395 country-industry pairs is 2.1621, with a standard deviation of 0.7482. This suggests that on average, a country-industry enters the production process about one stage before final uses. The 25^{th}, 50^{th}, and the 75^{th} percentile of the upstreamness values are 1.5786, 2.1074, and 2.6787, respectively.

It is interesting to note that the upstreamness values I construct are comparable to the U.S. industry-level upstreamness measure constructed by Antràs et al. (2012). Their measure of upstreamness ranges from a minimum of 1 to a maximum of 4.65 (petrochemicals). The mean value across 426 industries is 2.09, with a standard deviation of 0.85. While Antràs et al. (2012) uses highly granular industry-level data for United States only, my upstreamness measure captures the average production line position for a combination of country and industry by exploiting the linkages in the ICIO data.

To illustrate the industry composition of this measure, Table 11 lists the five most downstream versus upstream industries identified in most countries of the sample. Arts and entertainment, service activities, transport equipment, food products, beverages and tobacco, and motor vehicles are some of the most downstream industries, with their sectoral outputs being less than one stage from the final uses. In contrast, chemical and chemical products, basic metals, mining and quarrying (both energy producing and non-energy producing), and mining support service activities are among the most upstream industries which are associated with the largest number of countries in the sample.

Table 11. Least and Most Upstream Industries for Most Countries in The Sample

ISIC Rev.4 Industry	Upstreamness
Arts, entertainment and recreation (D90T93)	1.3677
Other service activities (D94T96)	1.4914
Other transport equipment (D30)	1.6541
Food products, beverages and tobacco (D10T12)	1.6579
Motor vehicles, trailers and semi-trailers (D29)	1.6856
Chemical and chemical products (D20)	2.9259
Basic metals (D24)	3.2781
Mining and quarrying, non-energy producing products (D07T08)	3.4789
Mining and quarrying, energy producing products (D05T06)	3.5071
Mining support service activities (D09)	3.5106

Sources: Author's calculations based on the OECD ICIO tables for year 2014.

Based on the 25th, median, and 75th percentile values, I group all upstreamness values into four categories: "Extremely Downstream" ($U_i \leq 1.5786$); "Relatively Downstream" ($1.5786 < U_i \leq 2.1074$); "Relatively Upstream" ($2.1074 < U_i \leq 2.6787$); and "Extremely Upstream" ($U_i > 2.6787$). Figure 12 shows the box plot of upstreamness by category. Over 75 percent of the country-industry pairs enter into production processes fewer than two stages before final use, while those categorized as "Extremely Upstream" have widely dispersed upstreamness values.

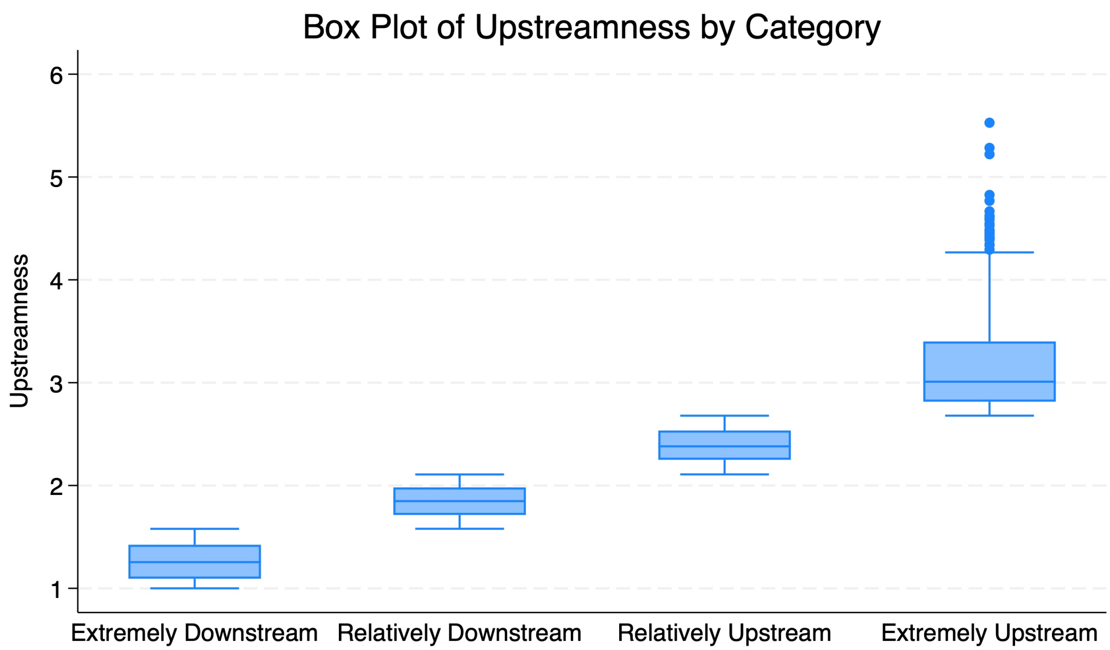
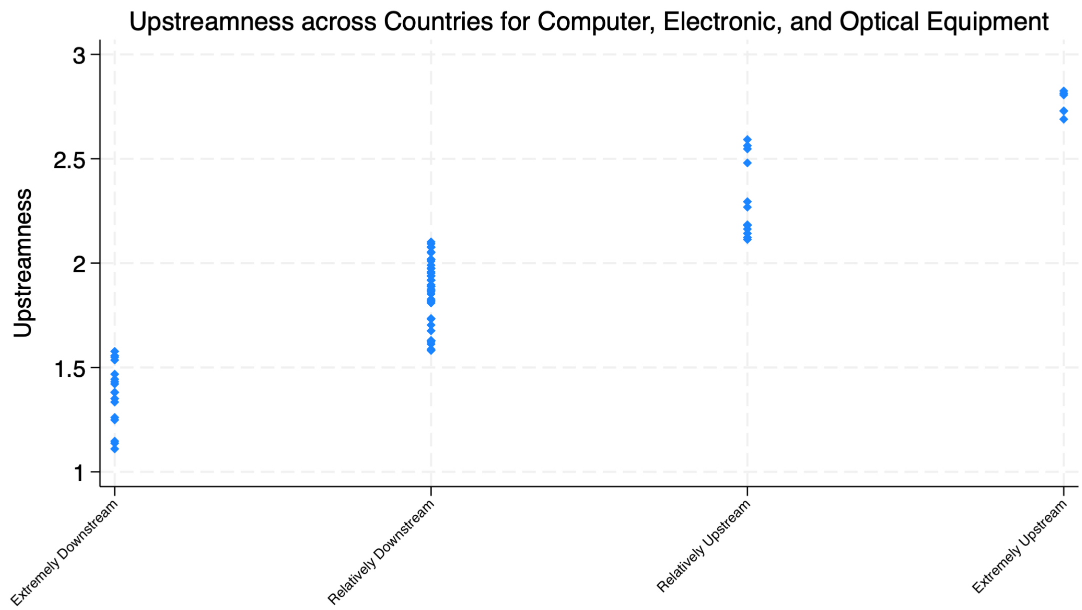


Figure 12. Box Plot of Upstreamness Values by Category

Sources: Author's calculations based on the OECD ICIO tables for year 2014.

It is also worth noting that the dispersions of upstreamness values across countries differ considerably by industry. Figure 13 illustrates the distributions of upstreamness values across countries for computer, electronic, and optical equipment (D26) versus for mining and quarrying, energy producing products (D05T06). For the former industry, countries participate in the value chains at different production line positions. In contrast, the vast majority of countries producing gross outputs in the mining and quarrying industry contribute to the global production line from an extremely upstream position. This indicates that countries involved in producing and trading generic products, such as processing raw materials, lack diversity in the positions within the value chains. The opposite can be argued for countries involved in the production and trade of differentiated products, which likely embody various degrees of product diversity and sophistication.



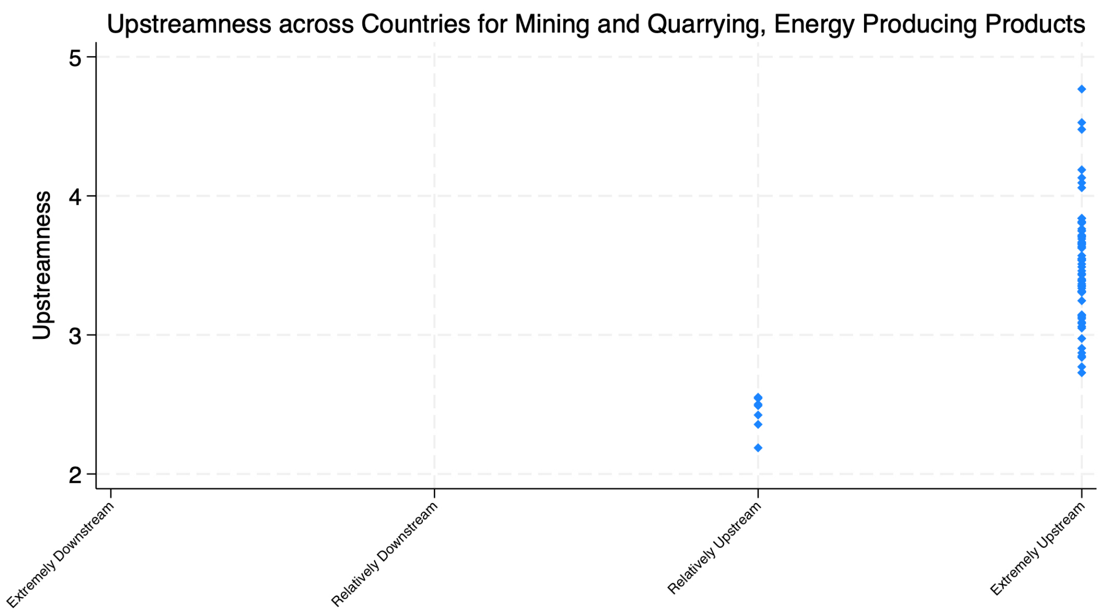


Figure 13. Upstreamness Values across Countries for Computer, Electronic, and Optical Equipment (Top) versus Mining and Quarrying, Energy Producing Products (Bottom)

Sources: Author's calculations based on the OECD ICIO tables for year 2014.

To examine the heterogeneous impact of participating in GVCs on export quality upgrading based on the upstreamness of a country-industry pair, I separate the full sample into four subsamples using the above-mentioned upstreamness categories and rerun selected baseline specifications.[14] Table 12 reports the subsample analyses, such that a country-industry pair is Extremely Downstream (columns (1) and (2)), Relatively Downstream (columns (3) and (4)), Relatively Upstream (columns (5) and (6)), or Extremely Upstream (columns (7) and (8)). Two conclusions can be drawn from these results. First, the impact of participating in GVCs on an increase in export quality is statistically significant for all upstreamness categories. Increasing the *GVC Participation Index* by one percentage point improves export quality by between 0.15 percent and 1.10 percent. More importantly, regression results in columns (2), (4), and (6) show that an increase in *Forward GVC Participation* is driving the significant impact on export quality upgrading when a country-industry pair is in either a downstream or a relatively upstream position in the value chain. On the other hand, for country-industry pairs in extremely upstream positions of the production line, it is an increase in *Backward GVC Participation* that is driving the improvement in export quality.

These results are intuitive: Countries and sectors which produce gross outputs in a downstream or a relatively upstream position likely produce and trade differentiated products which are more diverse and/or more technologically complex. By strengthening their forward GVC linkages, they could potentially climb up the quality ladder from learning-by-doing. The same development strategy may be less feasible for countries and industries which primarily contribute to the extremely upstream positions of the value chains. Since the nature of their products tends to be more generic and less technologically complex, it may be futile to jump-start the development process by relying on the existing comparative advantage and exporting the same products solely in larger quantities. Alternatively, these countries and industries may benefit from importing a higher share of foreign value-added, which likely embodies technologies they do not currently possess and may not have the resources to develop independently. By learning from industry leaders, these countries and industries may achieve leapfrogging in a more efficient manner, therefore changing its comparative advantage dynamically.

[14] I have also tried running the regressions by creating an interaction term "GVC indicator x Upstreamness categories", but this functional form does not pass the specification test in the two-step system-GMM post-estimation tests. This means that in this particular case, the functional form is misspecified. Therefore, I choose to split the full sample into four categories instead.

Table 12. Effects of GVC Trade on Export Quality by Country-Industry's Upstreamness Category

Dependent Variable: Ln(EQ)	(1) Extremely Downstream	(2) Extremely Downstream	(3) Relatively Downstream	(4) Relatively Downstream	(5) Relatively Upstream	(6) Relatively Upstream	(7) Extremely Upstream	(8) Extremely Upstream
1-Year Lag of Ln(EQ)	0.3715***	0.7201***	0.3700***	0.4480***	0.4792***	0.4647***	0.4812***	0.5805***
	(0.1385)	(0.1176)	(0.0503)	(0.0617)	(0.0510)	(0.0578)	(0.1267)	(0.1133)
1-Year Lag of GVC	0.0110*		0.0032**		0.0015*		0.0041**	
Participation Index (%)	(0.0066)		(0.0015)		(0.0009)		(0.0020)	
1-Year Lag of For-		0.0145**		0.0075***		0.0141***		0.0002
ward GVC Participation (%)		(0.0072)		(0.0029)		(0.0041)		(0.0020)
1-Year Lag of Back-		0.0019		0.0005		-0.0016		0.0082**
ward GVC Participation (%)		(0.0035)		(0.0014)		(0.0015)		(0.0033)
1-Year Lag of	0.0635***	0.0436*	0.0489***	0.0381***	0.0315***	0.0336***	0.0314**	0.0423***
Ln(GDP Per Capita)	(0.0217)	(0.0225)	(0.0102)	(0.0114)	(0.0077)	(0.0086)	(0.0128)	(0.0142)
1-Year Lag of	-0.0186	-0.0397	-0.0269	-0.0105	0.0153	0.0426*	0.0299	-0.0217
Ln(Human Capital)	(0.0327)	(0.0312)	(0.0204)	(0.0232)	(0.0176)	(0.0228)	(0.0335)	(0.0368)
1-Year Lag of FDI Net	0	-0.0002	0	0	0	0.0001	0.0001	-0.0001
Inflows (% of GDP)	(0.0001)	(0.0003)	0	0	0	(0.0001)	(0.0001)	(0.0001)
1-Year Lag of Invest-	0.0009	-0.0007	0.0004*	0.0002	0	0	0.0003	0.0007
ment (% of GDP)	(0.0006)	(0.0006)	(0.0002)	(0.0003)	(0.0003)	(0.0003)	(0.0005)	(0.0005)
1-Year Lag of	-0.0001	-0.0016	0.0001	0.0001	-0.0001	-0.0001	0.0003	0.0001
Institutional Quality	(0.0001)	(0.0017)	(0.0001)	(0.0001)	(0.0001)	(0.0001)	(0.0002)	(0.0003)
1-Year Lag of	-0.0018	-0.0052	0.0002	-0.0012	0.0039	0.0021	-0.0076	-0.0123
Ln(Capital Stock)	(0.0038)	(0.0039)	(0.0032)	(0.0039)	(0.0035)	(0.0041)	(0.0061)	(0.0078)
Constant	-0.6890***	-0.3323	-0.5372***	-0.4126***	-0.4373***	-0.4677***	-0.3110*	-0.2970*
	(0.2113)	(0.2068)	(0.0721)	(0.0769)	(0.0813)	(0.0920)	(0.1716)	(0.1690)
Observations	3,888	3,888	8,178	8,178	7,543	7,543	9,278	9,278
# of Country-Industry Units	237	237	454	454	415	415	516	516
A-B test for AR(1)	0.001	0	0	0	0	0	0	0
A-B test for AR(2)	0.462	0.184	0.865	0.736	0.521	0.537	0.689	0.862
Hansen Test of Overid.	0.795	0.564	0.345	0.701	0.217	0.373	0.120	0.123
Diff-in-Hansen: Excl. Group	0.594	0.777	0.520	0.615	0.192	0.273	0.105	0.127
Diff-in-Hansen: Diff.	0.783	0.216	0.108	0.635	0.470	0.572	0.431	0.295
# of Instruments	43	55	91	55	83	55	83	55

Notes: Results are generated via two-step system-GMM. Heteroskedasticity-robust and autocorrelation-robust standard errors are in parentheses. Coefficients for the time fixed effects are omitted for brevity. $^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$.

6 Discussion and Conclusion

The global economy has experienced increasing production fragmentation in the recent decades, suggesting that the world has become more interconnected than ever. Motivated by the rise in GVC trade and its potential dynamic gains and welfare implications, I examine the causal impact of participating in GVC trade on export quality upgrading, study the heterogeneous impact among countries and industries, and construct a country-industry upstreamness measure to analyze the impact of GVC trade on quality upgrading along different positions on the value chains. Relying on the *OECD TiVA (2021)* and the *IMF Export Diversification and Quality Databases*, I estimate the causal impact on a panel dataset which covers 61 countries and 28 industries from 1995 to 2014. Using the two-step system-GMM estimator, I find strong and robust evidence that participating in GVC trade has a positive and statistically significant impact on export quality. This impact is primarily and consistently driven by forward GVC linkages, while the impact of backward GVC linkages is sensitive to specifications.

Country-level heterogeneities suggest three patterns. First, the impact of increasing forward GVC participation on export quality is observed in both advanced and EMDE countries, and the impact on EMDE countries more than doubles the impact on advanced countries. Second, the significant effect is observed among countries which successfully transitioned into a higher income status during the sample period. Third, the impact is observed particularly among the East Asia and Pacific subsample. In terms of industry-level heterogeneities, empirical evidence reveals three patterns. First, the positive and significant effect is primarily driven by manufacturing industries. Second, increasing GVC integration in sectors with low R&D intensities links to a decrease in sectoral export quality. Third, increasing the share of sectoral differentiated products has a strong and positive impact on export quality. Furthermore, subsample analyses based on the upstreamness measure suggest that country-industry pairs whose production positions are closer to final uses can experience quality upgrading through intensifying forward GVC linkages, while those whose production positions are extremely far from final uses can benefit through facilitating backward GVC linkages. Regression results also highlight the impact of domestic factors such as GDP per capita, institutional quality, investment, FDI, and human capital on export quality upgrading. While a positive impact has been shown for all of these factors, the impact of GDP per capita is consistent and robust across specifications and analyses.

This paper has crucial policy implications regarding trade in value-added. The empirical evidence suggests that facilitating forward GVC linkages, defined as the domestic value-added embodied in foreign exports as a share of origin country's gross exports, is the dominant source of export quality upgrading. On the other hand, an increasing dependence of backward GVC linkages, interpreted as the magnitude of industry foreign value-added contribution to sectoral exports as a share of receiving country's total gross exports, does not appear to significantly prompt countries and sectors to climb the quality ladder. Intuitively, forward linkages can improve export quality and create knowledge spillovers through learning-by-doing. Policymakers should target policies which increase the value-added contents exported to and utilized by the rest of the world. These policies include facilitating industrial innovation through R&D, utilizing human capital in the production process, attracting investment and FDI which lead to capital accumulation, and improving domestic institutional quality, which result in the stabilization of the economy, market-oriented regulations, and a vibrant environment for entrepreneurship. Economies with robust production and export capabilities may be more resilient to negative shocks and are more likely to experience a smooth recovery. Meanwhile, an increasing reliance on foreign value-added contents may subject economies to stagnation and recession in the presence of negative exogenous shocks. In recent years, shocks including natural disasters, supply chain constraints, and geopolitical instabilities have put pressures on countries strongly constrained by the global economy.

In addition, participating in GVC trade is linked to unequal gains in terms of export quality upgrading, which also has important policy implications on inequality. Empirical evidence reveals several seemingly contradictory patterns: First, the positive effect on export quality upgrading is more prominent for country-industry pairs with high existing export qualities, suggesting an absence of catch-up effect in the sample. Second, the positive impact on export quality upgrading for EMDEs is nearly three times the impact for advanced economies, and the significant effect is observed among countries which experienced a positive income level transition between 1995 and 2014. Third, for country-industry pairs with low existing R&D intensities, facilitating forward GVC linkages is in fact associated with a reduction of export quality. These discrepancies can be reconciled in Table C1, by the fact that the sample of EMDE countries only include lower-middle-income and upper-middle-income countries, but not lower-income countries. The findings suggest that the gains are most likely concentrated in a certain subset of EMDEs which export lots of manufactures (such as Mexico, China, India), and the benefits are not equally felt across all EMDEs. Many EMDEs, including lower-income countries and countries in South America, still heavily specialize in primary commodity exports. These country-industry pairs likely receive smaller benefits in export quality from participating in GVC trade.

Furthermore, the empirical exercise of the impact on export quality based on countries and industries' upstreamness position suggests that developing countries and advanced countries should pursue different development policies by engaging in GVC trade in different ways. For advanced economies-industry units which produce more technologically complex goods that are closer to final consumption, they can maintain their industrial quality frontier status and amplify their advantage by contributing to the value-added contents through forward GVC linkages. For economies-industry units which specialize in generic commodities and are in the extremely upstream positions of the value chains (far from final consumption), engaging in GVC trade by relying on the existing comparative advantage may not be an effective development strategy. These countries may not have advanced machinery to benefit from automation, or have ample resources to invest in R&D to spearhead innovation. Instead, by importing foreign value-added contents through backward GVC participation, these countries may benefit from the technological components embedded in the imported intermediate inputs, which potentially lead to technological leapfrogging.

To the best of my knowledge, this paper is one of the few papers which explore the impact of GVC trade on export quality upgrading. Along with export diversification, quality upgrading is considered a major indicator and a necessary condition for structural transformation. Due to data limitations, lower-income countries, especially sub-Saharan Africa (except for South Africa), are omitted from the analyses. Therefore, my sample over-represents high-income and middle-income countries, which is not representative of the global economy. As a result, I acknowledge the limitations of my empirical analyses and would caution against applying the empirical results and policy implications to lower-income countries.

Further research on this topic remains promising. As inter-country input-output data continues to be made available, this study can be expanded to include more developing economies to make the sample more representative of the world. Furthermore, future export quality measures which can incorporate the concept of "trade in intermediates" instead of "trade in goods" will improve this study in more profound ways.

References

Amighini, A. and M. Sanfilippo (2014). Impact of south–south fdi and trade on the export upgrading of african economies. *World Development 64*, 1–17.

Andersen, T. G. and B. E. Sørensen (1996). Gmm estimation of a stochastic volatility model: A monte carlo study. *Journal of Business & Economic Statistics 14*(3), 328–352.

Anderson, T. W. and C. Hsiao (1981). Estimation of dynamic models with error components. *Journal of The American Statistical Association 76*(375), 598–606.

Anderson, T. W. and C. Hsiao (1982). Formulation and estimation of dynamic models using panel data. *Journal of Econometrics 18*(1), 47–82.

Antràs, P., D. Chor, T. Fally, and R. Hillberry (2012). Measuring the upstreamness of production and trade flows. *American Economic Review 102*(3), 412–416.

Arellano, M. and S. Bond (1991). Some tests of specification for panel data: Monte carlo evidence and an application to employment equations. *Review of Economic Studies 58*(2), 277–297.

Arellano, M. and O. Bover (1995). Another look at the instrumental variable estimation of error-components models. *Journal of Econometrics 68*(1), 29–51.

Barro, R. J. and J. W. Lee (2013). A new data set of educational attainment in the world, 1950–2010. *Journal of Development Economics 104*, 184–198.

Bas, M. and V. Strauss-Kahn (2015). Input-trade liberalization, export prices and quality upgrading. *Journal of International Economics 95*(2), 250–262.

Belotti, F., A. Borin, and M. Mancini (2020). Icio: Economic analysis with intercountry input-output tables in stata. (9156).

Blundell, R. and S. Bond (1998). Initial conditions and moment restrictions in dynamic panel data models. *Journal of Econometrics 1987*(1), 115–143.

Borin, A. and M. Mancini (2019). Measuring what matters in global value chains and value-added trade. (8804).

Bowsher, C. G. (2002). On testing overidentifying restrictions in dynamic panel data models. *Economics Letters 77*(2), 211–220.

Bradsher, K. (2024). China came to dominate the world in solar energy. Accessed: March 7, 2024.

Fally, T. (2011). On the fragmentation of production in the u.s.

Feenstra, R. C. and G. H. Hanson (1997). Foreign direct investment and relative wages: Evidence from mexico's maquiladoras. *Journal of International Economics 42*, 371–393.

Galindo-Rueda, F. and F. Verger (2016). Oecd taxonomy of economic activities based on r&d intensity.

Goldberg, P. K., A. Khandelwal, N. Pavcnik, and P. Topalova (2010). Imported intermediate inputs and domestic product growth: Evidence from india. *Quarterly Journal of Economics 125*(4), 1727–1767.

Grossman, G. M. and E. Helpman (1993). *Innovation and Growth in the Global Economy.* MIT Press.

Hallak, J. C. (2006). Product quality and the direction of trade. *Journal of International Economics 68*(1), 238–265.

Hansen, L. P. (1982). Large sample properties of generalized method of moments estimators. *Large Sample Properties of Generalized Method of Moments Estimators 50*(4), 1029–1054.

Henn, C., C. Papageorgiou, and N. Spatafora (2013). Export quality in developing countries. *International Monetary Fund*.

Holtz-Eakin, D., W. Newey, and H. S. Rosen (1988). Estimating vector autoregressions with panel data. *Econometrica: Journal of The Econometric Society 56*(6), 1371–1395.

Hummels, D. and P. J. Klenow (2005). The variety and quality of a nation's exports. *American Economic Review 95*(3), 704–723.

Humphrey, J. and H. Schmitz (2002). How does insertion in global value chains affect upgrading in industrial clusters? *Regional Studies 36*(9), 1017–1027.

Johnson, R. C. and G. Noguera (2017). A portrait of trade in value-added over four decades. *Review of Economics and Statistics 99*(5), 896–911.

Kaplinsky, R. and J. Readman (2005). Globalization and upgrading: what can (and cannot) be learnt from international trade statistics in the wood furniture sector? *Industrial and Corporate Change 14*(4), 679–703.

Keller, W. (2002). Trade and the transmission of technology. *Journal of Economic Growth 7*, 5–24.

Kripfganz, S. (2019). Generalized method of moments estimation of linear dynamic panel-data models. *London Stata Conference 17.*

Kugler, M. and E. Verhoogen (2008). The quality-complementarity hypothesis: Theory and evidence from colombia. (w14418).

Kummritz, Victor, T. D. and D. Winkler (2017). Economic upgrading through global value chain participation: Which policies increase the value added gains? (8007).

Loungani, P. and A. Razin (2001). How beneficial is foreign direct investment for developing countries? *Finance & Development 38*(2), 6–6.

Marcato, M. B. and C. T. Baltar (2020). Economic upgrading in global value chains: Concepts and measures. *Revista brasileira de inovaçao 19*.

Melitz, M. J. (2003). The impact of trade on intra-industry reallocations and aggregate industry productivity. *Econometrica 71*(6), 1695–1725.

Ndubuisi, G. and S. Owusu (2021). How important is gvc participation to export upgrading? *The World Economy 44*(10), 2887–2908.

Nickell, S. (1981). Biases in dynamic models with fixed effects. *Econometrica: Journal of The Econometric Society 49*(6), 1417–1426.

Pahl, S. and M. P. Timmer (2020). Do global value chains enhance economic upgrading? a long view. *Journal of Development Studies 56*(9), 1683–1705.

Psacharopoulos, G. (1994). Returns to investment in education: A global update. *World Development 22*(9), 1325–1343.

Rauch, J. E. (1999). Networks versus markets in international trade. *Journal of International Economics 48*(1), 7–35.

Roodman, D. (2009). How to do xtabond2: An introduction to difference and system gmm in stata. *The Stata Journal 9*(1), 86–136.

Schott, P. K. (2004). Across-product versus within-product specialization in international trade. *Quarterly Journal of Economics 119*(2), 647–678.

Taglioni, D. and D. Winkler (2016). *Making global value chains work for development.* World Bank Publications.

Ullah, S., P. Akhtar, and G. Zaefarian (2018). Dealing with endogeneity bias: The generalized method of moments (gmm) for panel data. *Industrial Marketing Management 71*, 69–78.

UNCTAD (2016). Structural transformation and industrial policy. https://unctad.org/system/files/official-document/gds2016d1_en.pdf, United Nations Conference on Trade and Development.

WBG (2020). World development report 2020: Trading for development in the age of global value chains. https://www.worldbank.org/en/publication/wdr2020, World Bank Group.

Wintoki, M. Babajide, L. J. S. and J. M. Netter (2012). Endogeneity and the dynamics of internal corporate governance. *Journal of Financial Economics 105*(3), 581–606.

A Appendix One

N.	Code	Country	N.	Code	Country
1	AUS	Australia	39	ARG	Argentina
2	AUT	Austria	40	BRA	Brazil
3	BEL	Belgium	41	BRN	Brunei Darussalam
4	CAN	Canada	42	BGR	Bulgaria
5	CHL	Chile	43	KHM	Cambodia
6	COL	Colombia	44	CHN	China (People's Republic of)
7	CRI	Costa Rica	45	HRV	Croatia
8	CZE	Czech Republic	46	CYP	Cyprus[2]
9	DNK	Denmark	47	IND	India
10	EST	Estonia	48	IDN	Indonesia
11	FIN	Finland	49	HKG	Hong Kong, China
12	FRA	France	50	KAZ	Kazakhstan
13	DEU	Germany	51	LAO	Lao People's Democratic Rep.
14	GRC	Greece	52	MYS	Malaysia
15	HUN	Hungary	53	MLT	Malta
16	ISL	Iceland	54	MAR	Morocco
17	IRL	Ireland	55	MMR	Myanmar
18	ISR	Israel[1]	56	PER	Peru
19	ITA	Italy	57	PHL	Philippines
20	JPN	Japan	58	ROU	Romania
21	KOR	Korea	59	RUS	Russian Federation
22	LVA	Latvia	60	SAU	Saudi Arabia
23	LTU	Lithuania	61	SGP	Singapore
24	LUX	Luxembourg	62	ZAF	South Africa
25	MEX	Mexico	63	TWN	Chinese Taipei
26	NLD	Netherlands	64	THA	Thailand
27	NZL	New Zealand	65	TUN	Tunisia
28	NOR	Norway	66	VNM	Viet Nam
29	POL	Poland	67	ROW	Rest of the World
30	PRT	Portugal			
31	SVK	Slovak Republic			
32	SVN	Slovenia			
33	ESP	Spain			
34	SWE	Sweden			
35	CHE	Switzerland			
36	TUR	Turkey			
37	GBR	United Kingdom			
38	USA	United States			

Appendix Figure A1. OECD TiVA (2021) Country Coverage

Source: OECD TiVA (2021).

B Appendix Two

	Code	Industry	ISIC Rev.4 Divisions	ISIC Rev.4 Sections
1	D01T02	Agriculture, hunting, forestry	01, 02	A
2	D03	Fishing and aquaculture	03	
3	D05T06	Mining and quarrying, energy producing products	05, 06	B
4	D07T08	Mining and quarrying, non-energy producing products	07, 08	
5	D09	Mining support service activities	09	
6	D10T12	Food products, beverages and tobacco	10, 11, 12	C
7	D13T15	Textiles, textile products, leather and footwear	13, 14, 15	
8	D16	Wood and products of wood and cork	16	
9	D17T18	Paper products and printing	17, 18	
10	D19	Coke and refined petroleum products	19	
11	D20	Chemical and chemical products	20	
12	D21	Pharmaceuticals, medicinal chemical and botanical products	21	
13	D22	Rubber and plastics products	22	
14	D23	Other non-metallic mineral products	23	
15	D24	Basic metals	24	
16	D25	Fabricated metal products	25	
17	D26	Computer, electronic and optical equipment	26	
18	D27	Electrical equipment	27	
19	D28	Machinery and equipment, nec	28	
20	D29	Motor vehicles, trailers and semi-trailers	29	
21	D30	Other transport equipment	30	
22	D31T33	Manufacturing nec; repair and installation of machinery and equipment	31, 32, 33	
23	D35	Electricity, gas, steam and air conditioning supply	35	D
24	D36T39	Water supply; sewerage, waste management and remediation activities	36, 37, 38, 39	E
25	D41T43	Construction	41, 42, 43	F
26	D45T47	Wholesale and retail trade; repair of motor vehicles	45, 46, 47	G
27	D49	Land transport and transport via pipelines	49	H
28	D50	Water transport	50	
29	D51	Air transport	51	
30	D52	Warehousing and support activities for transportation	52	
31	D53	Postal and courier activities	53	
32	D55T56	Accommodation and food service activities	55, 56	I
33	D58T60	Publishing, audiovisual and broadcasting activities	58, 59, 60	J
34	D61	Telecommunications	61	
35	D62T63	IT and other information services	62, 63	
36	D64T66	Financial and insurance activities	64, 65, 66	K
37	D68	Real estate activities	68	L
38	D69T75	Professional, scientific and technical activities	69 to 75	M
39	D77T82	Administrative and support services	77 to 82	N
40	D84	Public administration and defence; compulsory social security	84	O
41	D85	Education	85	P
42	D86T88	Human health and social work activities	86, 87, 88	Q
43	D90T93	Arts, entertainment and recreation	90, 91, 92, 93	R
44	D94T96	Other service activities	94,95, 96	S
45	D97T98	Activities of households as employers; undifferentiated goods- and services-producing activities of households for own use	97, 98	T

Appendix Figure B1. OECD TiVA (2021) Industry Coverage

Source: OECD TiVA (2021).

C Appendix Three

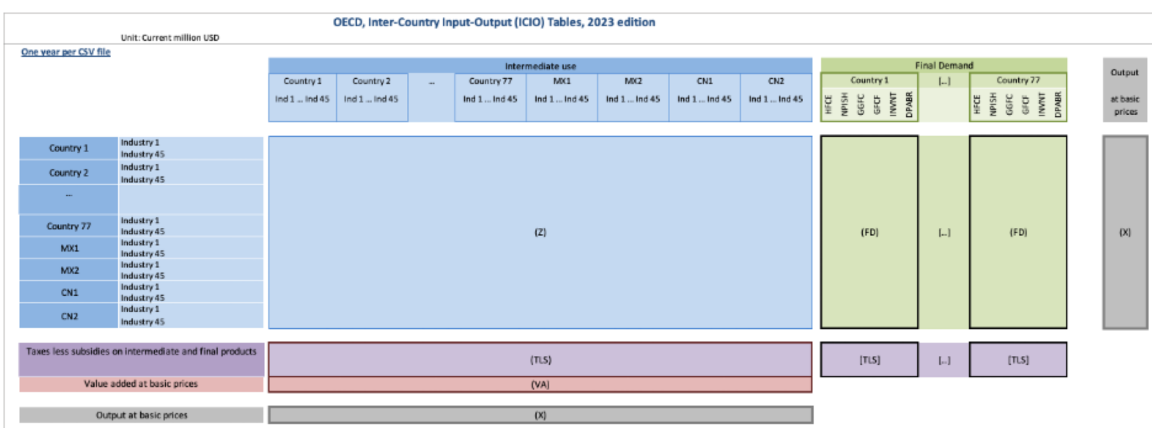
Appendix Table C1. Subsample Analyses of Effects of GVC Trade on Export Quality by Income Level

Dependent Variable: Ln(EQ)	(1) Lower Middle Income	(2) Lower Middle Income	(3) Upper Middle Income	(4) Upper Middle Income	(5) High Income	(6) High Income
1-Year Lag of Ln(EQ)	0.5914***	0.5281***	0.7111***	0.4806***	0.8321***	0.6706***
	(0.1066)	(0.1022)	(0.1340)	(0.0583)	(0.0757)	(0.1526)
1-Year Lag of GVC	0.0041*		0.0055*		0.0016**	
Participation Index (%)	(0.0024)		(0.0029)		(0.0007)	
1-Year Lag of For-		0.0076		0.0062**		0.0008
ward GVC Participation (%)		(0.0105)		(0.0028)		(0.0018)
1-Year Lag of Back-		0.0012		-0.0018		0.0014
ward GVC Participation (%)		(0.0033)		(0.0040)		(0.0011)
1-Year Lag of	0.0566***	0.0574***	0.0282**	0.0244**	0.0242*	0.0307**
ln(GDP Per Capita)	(0.0173)	(0.0134)	(0.0127)	(0.0098)	(0.0124)	(0.0145)
1-Year Lag of	-0.0122	0.0038	-0.0258	-0.0517*	0.0038	0.0735
Ln(Human Capital)	(0.0521)	(0.0495)	(0.0360)	(0.0303)	(0.0360)	(0.0509)
1-Year Lag of FDI	0.0011	0.0002	0	0.0001	-0.0001	0.0001
Net Inflows (% of GDP)	(0.0011)	(0.0009)	(0.0004)	(0.0003)	(0.0001)	(0.0001)
1-Year Lag of	-0.0014**	-0.0014***	0.0005*	0.0003	-0.0001	0.0004
Investment (% of GDP)	(0.0006)	(0.0005)	(0.0003)	(0.0003)	(0.0002)	(0.0003)
1-Year Lag of	0.0002	0.0003*	-0.0004	0.0002**	0.0006	-0.0055
Institutional Quality	(0.0002)	(0.0002)	(0.0007)	(0.0001)	(0.0008)	(0.0035)
1-Year Lag of	-0.0010	-0.0053	0.0036	-0.0015	-0.0046	-0.0030
Ln(Capital Stock)	(0.0089)	(0.0066)	(0.0043)	(0.0045)	(0.0041)	(0.0031)
Constant	-0.5176***	-0.4827***	-0.3529**	-0.2424*	-0.2056*	-0.3629**
	(0.1613)	(0.1313)	(0.1529)	(0.1373)	(0.1223)	(0.1608)
Observations	3,086	3,086	7,457	7,457	18,470	18,470
# of Country-Industry Units	206	206	402	402	1,023	1,023
AB test for AR(1)	0.0002	0	0.0004	0.0002	0	0
AB test for AR(2)	0.265	0.320	0.941	0.626	0.626	0.752
Hansen Test of Overid. Res.	0.566	0.481	0.100	0.067	0.304	0.394
Diff-in-Hansen: Excl. Group	0.279	0.478	0.115	0.086	0.348	0.339
Diff-in-Hansen: Diff.	0.906	0.440	0.248	0.219	0.309	0.453
# of Instruments	51	82	51	82	43	46

Notes: Results are generated via two-step system-GMM. Countries' income classification is based on the World Bank Country and Lending Groups income classification. Heteroskedasticity-robust and autocorrelation-robust standard errors are in parentheses. Time fixed effects are omitted for brevity. $^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$.

D Appendix Four: Statistical Note on The Creation of Country-Industry Level Upstreamness Measure

As illustrated in Belotti et al. (2020), the OECD ICIO tables with $G = 76$ countries and $N = 45$ industries can be presented in the Appendix Figure D1 below. Z is the $GN \times GN$ matrix of Intermediate Inputs; each entry in the matrix represents the intermediate inputs produced by country r=1,2,. . . ,76 and industry i=1,2 ,. . . ,45 (rows) and used in country s=1,2,. . . ,76 and industry j=1,2,. . . ,45 (columns). Final Demand Y represents the vector of final goods and services completed in country r, industry i, and absorbed in country s in the form of Household Final Consumption Expenditure (HFCE), Non-Profit Institutions Serving Households (NPISH), General Government Final Consumption (GGFC), Gross Fixed Capital Formation (GFCF), Changes in Inventories and Valuables (INVNT), and Direct Purchases Abroad by Residents (DPABR). X represents the $GN \times 1$ vector of Gross Output produced in country r and industry i, which is equal to the sum of Intermediate Inputs and Final Demand. "TLS" stands for taxes less subsidies on intermediate and final products, and "VA" represents the $1 \times GN$ vector of value-added generated in country r and industry i. Each row in the ICIO models shows that the gross output of country r and industry i is used as intermediate inputs for different countries and industries, and as final products to fulfill domestic and foreign demand. ICIO models rely on crucial proportionality assumptions: The composition of inputs in sectoral productions does not vary by geographical destination of output, and it is identical between intermediate and final goods.



Appendix Figure D1. An Illustration of The Structure of OECD ICIO Tables

Source: OECD website.

For any given country r and industry i, each unit of its gross output can either be used as an intermediate input at home or abroad, or consumed as a final good:

$$X_{r,i} = \sum_{g=1}^{76} \sum_{n=1}^{45} Z_{rg,in} + \sum_{g=1}^{76} Y_{rg,i} \tag{21}$$

where $Z_{rg,in}$ represents the gross output produced by country r and industry i and used in country g and industry n, and $Y_{rg,i}$ represents the output consumed as final use both at home and abroad. I construct an intermediate inputs coefficients matrix A with dimensions $GN \times GN$ as follows. For each entry in matrix A, (Outputs as Intermediate Use) divided by (Gross Output – Changes in Inventories and Valuables) is equal to $\frac{Z_{rg,in}}{X_{r,i} - \sum_{g=1}^{76} INVNT_{rg,i}}$. The numerator comes directly from the ICIO tables, and the denominator is calculated as the sum of values in each row of the ICIO table, minus the values recorded under "Changes in Inventories and Valuables" for home and abroad. The fundamental relationship between gross output and final demand is given by:

$$X = (I - A)^{-1} Y = BY, \tag{22}$$

where B is the $GN \times GN$ "global" Leontief inverse matrix which calculates the total units of gross output in countries-industries of origin needed to produce a unit of final goods or services. Intuitively, matrix B accounts for the amount of gross output produced in every round of production: $B = I + A + A^2 + A^3 + \cdots = (I - A)^{-1}$. With this "global" Leontief inverse matrix, the formula $[I - A]^{-1}\mathbf{1}$, where $\mathbf{1}$ is a $GN \times 1$ column vector of ones, generates a column vector whose i-th entry is the Upstreamness measure U_i for a country-industry pair. For 25 country-industry pairs, the denominator "Gross Output – Changes in Inventories and Valuables" of the entry in matrix A equals zero. I perform listwise deletions on these country-industry pairs to ensure that the generated square matrix A is invertible.