Trade and Economic Growth: Does the Sophistication of Traded Goods Matter?

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Research Article

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Posted Date: July 20th, 2022

DOI: https://doi.org/10.21203/rs.3.rs-1861359/v1

Trade and Economic Growth: Does the Sophistication of Traded Goods Matter?*

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Friday 15^{th} July, 2022

Abstract

Following the seminal paper of Frankel and Romer (1999), 'Does trade cause growth?', the income effects of aggregate trade openness have been controversial. This research shows that the type of product that is traded has first-order effects while the overall trade intensity has second-order effects on per capita income because of (i) the hierarchical structure of learning-by-doing in products with different levels of sophistication of the production processes; and (ii) the fertility and education effects of trade specialization following the quantity-quality tradeoff framework of Galor and Mountford (2006). Using data on trade disaggregated by the level of technological sophistication of the production process for 223 countries over the 1962-2019 period, we find that (1) the growth effects of foreign trade differ widely across technology categories; (2) high-tech trade has permanent growth effects; and (3) a significant fraction of the income effects of trade are mediated through education and fertility.

Keywords: trade; economic growth; technology; learning-by-doing; quantity-quality tradeoff.

JEL Codes: F14, F43, J13, O11, O33.

*Helpful comments and suggestions from seminar participants at the University of Western Australia and, particularly, two anonymous referees are gratefully acknowledged. Jakob B. Madsen acknowledges financial support from the Australian Research Council (DP170100339; DP220102557).

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1 Introduction

The effect of trade on income growth has long been controversial. While most economic theories point toward positive growth effects of trade, early empirical evidence was plagued by reverse causality and omitted variable bias. Frankel and Romer (1999) proposed an instrumental variable identification strategy to ascertain causality. They used gravity equations based on geographic characteristics to predict bilateral trade between countries. However, the results based on their identification strategy remain mixed and sensitive to the choice of data, model specification, and the inclusion of confounding factors (Rodriguez and Rodrik, 2000; Irwin and Terviö, 2002; Ortega and Peri, 2014; Deij et al., 2021).

In this paper, we show that the use of aggregate trade data in per capita income regressions, as is typical in the existing literature, obscures the growth effects of trade openness. We posit that the effects of trade depend on the sophistication of the traded goods. With aggregate data, the conflicting income effects of trade in products of different levels of sophistication tend to cancel each other out, rendering the overall impact sensitive to sample selection. Thus, the composition of trade has first-order effects on income, whereas the income effects of aggregate trade are of second order.

Following the literature on the hierarchical structure of learning-by-doing, as outlined in the next section, it follows that trade in high-tech goods have positive productivity effects while trade in low-tech primary products have negative growth effects. Exports and imports of high-tech products are likely to promote R&D and production efficiency through scale effects, technology diffusion, and better quality of intermediate goods (Rivera-Batiz and Romer, 1991; Grossman and Helpman, 1995; Coe and Helpman, 1995; Madsen, 2007; Buera and Oberfield, 2020). Furthermore, by increasing returns to education, high-tech trade stimulates investment in human capital formation; thus, promoting future innovations. This virtuous cycle of human capital investment, innovation, and technology diffusion can set countries on a high-growth path (Galor and Mountford, 2006, 2008; Galor, 2022). Specializing in the production of unsophisticated products with low income elasticities and little scope for learning-by-doing, by contrast, entrenches countries in low-growth traps (Young, 1991).

This line of reasoning finds indirect support from history. Williamson (2013) shows that during the 1850-1913 globalization wave, the rich industrial core benefited from scale economies derived from trade, while the specialization in commodity exports lead to deindustrialization, rent seeking, and excessive commodity price volatility in the periphery. Galor and Mountford (2008) posit that trade during the early industrialization period enhanced the specialization of industrial economies in sophisticated production, which induced a rise in demand for skilled labor. This expedited the demographic transition in these economies, increased investment in human capital formation, and caused sustained growth in income per capita. Countries that specialized in unskilled non-industrial production, directed their gains from trade towards population growth, which slowed down their transition to sustained growth.

To test the learning-by-doing hypothesis, we begin by examining the effect of trade openness decomposed on product categories with different levels of sophistication on income per capita. Our analysis uses annual bilateral trade data from 223 countries covering the 1962-2019 period. Following the model in Young (1991), we rank traded goods by the level of technological sophistication of their production process. We use the classification from Lall (2000) to categorize goods into (i) primary products (AG), (ii) mining and quarrying (MQ), (iii) low-tech (LT) manufacturing, and (iv) high-tech (HT) manufacturing. To account for endogeneity, we use the identification strategy of Frankel and Romer (1999) while allowing for time-varying trade distance-resistance by ships and aircraft, as suggested by Feyrer (2019). We also interact all the other geographic predictors in the gravity equations with year fixed effects to allow for dynamics in the role of these factors. Several checks for the validity of the exclusion restriction support our identification strategy.

While the learning-by-doing model of Young (1991) goes a long way in explaining the income effects of differentiated trade, it fails to explain our finding that specialization in low-tech manufacturing promotes growth despite its meagre learning-by-doing potential. This is not because the hierarchical model is at fault, but because low-tech manufacturing influences the tradeoff between fertility and education through the opportunity costs of childbearing and the gender wage gap. A crucial ingredient missing from the learning-by-doing model in explaining the income effects of foreign trade, is that specialization in low-tech manufacturing can promote the fertility transition and the subsequent growth effects of fertility and education following the quantity-quality (QQ) tradeoff framework. To this end, we incorporate fertility and education into the analysis following the research of Galor and Mountford (2008). Based on the QQ-tradeoff, Galor and Mountford (2008) show that the gains from trade in advanced countries have been directed towards investment in education, while these gains have been channeled towards population growth in developing countries.

To investigate the income-effects of trade on income through the channels of fertility and education, we regress school enrollment rates and fertility on trade decomposed on different technology groups and test whether fertility and education mediate the income effects of trade. There are three reasons to introduce the QQ-tradeoff framework into the analysis. First, trade specialization is the mechanism through which hierarchical learning-by-doing influences growth and, as such, it does not give an independent role for a trade-induced increases in women's labor market opportunities and reductions in the gender wage gap that will enhance human capital formation and promote growth. This means that low-tech manufacturing reduces income because of low learning-by-doing opportunities. However, since low-tech manufacturing is dominated by female-labor intensive production, such as in textiles, toys, and food processing, an expansion of low-tech manufacturing reduces the gender wage gap, which in turn reduces fertility and promotes education (see, e.g., Galor and Weil (1996) and Madsen et al. (2020)). Recent research shows that the fertility transition in today's advanced countries, which started around 1870, was pivotal for the productivity expansion in the 20th century and the Great Divergence (Galor and Weil, 2000; Galor and Mountford, 2008; Dalgaard and Strulik, 2013; Madsen et al., 2020).

Second, the fertility and education effects of decomposed trade are strong joint robustness checks of the leaning-by-doing model of Young (1991) and the QQ-tradeoff model of Galor and Mountford (2008). In the strongest case scenario, all estimated import and export elasticities with respect to categorized trade are consistent across the two models. As will become apparent in the empirical section, the underlying fertility and educational effects of trade are crucial for understanding the dichotomy between the export and import elasticities in the income regressions. Third, the feed-back effects from fertility and education to growth, however, cannot easily be captured by reduced form income regressions because it takes years before the growth effects of a fertility reduction are borne out due to time spent in the educational system, on-the-job learning by doing, and the time it takes for young age cohorts to replace older workers that exit the labor market.

Our theory and empirical methodology builds on a number of earlier studies (Young, 1991; Galor and Weil, 1996; Frankel and Romer, 1999; Yanikkaya, 2003; Galor and Mountford, 2008; Andersen and Dalgaard, 2011; Ortega and Peri, 2014; Ang et al., 2015; Pascali, 2017; Feyrer, 2009, 2019; Deij et al., 2021). The studies closest to ours are Coe and Helpman (1995), Coe et al. (1997), Madsen (2007), Galor and Mountford (2008), Kim and Lin (2009), and Ang et al. (2015). Using data for advanced countries, Coe and Helpman (1995) and Madsen (2007) find significant positive associations between R&D stocks of trading countries and total factor productivity. However, they do not check for causality using instruments. Coe et al. (1997) find positive productivity effects of R&D knowledge spillovers from advanced to developing countries based on FE-OLS regressions. Galor and Mountford (2008) find that while trade increases education and reduces fertility in the OECD countries, it has the opposite effect in non-OECD countries. Kim and Lin (2009) show that aggregate international trade benefits advanced countries but harms developing countries. Both of these studies use Frankel and Romer (1999)'s identification strategy and aggregate trade data. Ang et al. (2015) show that R&D intensity promotes exports in East Asia. However, none of these studies examine the effects of trade disaggregated by the level of sophistication of production on productivity, fertility and human capital formation and, therefore, do not uncover some key implications of trade on development .

The remainder of the paper is organized as follows. In the next section, we summarize the relevant theoretical literature on the macroeconomic effects of trade decomposed on technology categories. Section 3 sets out our empirical strategy and discusses the data. We present our main findings on the effect of trade on income in Section 4 and in Section 5 we test whether various sophistication levels of traded products have permanent growth effects as opposed to one-off income effects as in the income baseline estimates. In Section 6 we undertake several tests for the exclusion restriction. In Section 7, we explore the effect of differentiated trade on fertility and education, while Section 8 derives the quantitative effects of decomposed trade for income, fertility and education. Section 9 concludes the paper.

2 The nexus between trade and growth: Winners and losers

Gains from specialization, scale effects and knowledge-diffusion have been stressed in the literature on the income effects of trade (Buera and Oberfield, 2020). Initial gains from trade can originate from countries specialiszing in the products they hold comparative advantage in (Ricardo, 1821). But this alone cannot explain the longer term income effects of trade. The existing theories on the growth effects (i) theories about the direct positive growth effects of trade, (ii) theories about the direct negative growth effects of trade, (iii) theories about the indirect growth effects of trade through changes in human capital investment and fertility. We briefly recap these theories below.

2.1 Winners: Positive growth effects of trade

The innovation-based growth literature links trade and growth via four main channels: (i) access to foreign intermediate inputs with embodied knowledge, (ii) expansion in the market demand for new varieties, (iii) international knowledge diffusion, and (iv) destruction of unproductive firms.

First, access to international intermediate goods increases productivity through improved quality and larger variety of inputs used in production, particularly, machinery (Grossman and Helpman, 1991; Coe and Helpman, 1995). Second, an expansion of the market size raises the profitability of R&D investment, shifts resources from production to R&D, and consequently increases the long-run rate of innovation and productivity growth in all trading countries (Grossman and Helpman, 1991; Rivera-Batiz and Romer, 1991; Dinopoulos and Segerstrom, 1999). Third, trade expansions facilitate knowledge diffusion across country borders, which increases the stock of general knowledge available locally. This speeds up the innovation rate in the R&D sector provided that the skilled labor and know-how available locally are complementary to the new and advanced technologies (Basu and Weil, 1998; Acemoglu and Zilibotti, 2001).

Fourth, trade openness causes less productive firms to exit the market and allows for cross-firm resource reallocation from less to more productive firms (Hsieh and Klenow, 2009). Furthermore, selection on productivity shifts the productivity distribution of incumbent firms upwards and leads to technology diffusion (Sampson, 2016). As technology diffusion raises average productivity, low-productivity firms become unprofitable, which generates further selection. In equilibrium, the positive feedback from technology diffusion and selection results in endogenous growth driven by the dynamic selection mechanism (Sampson, 2016).

2.2 Losers: Negative productivity effects of trade openness

The direct benefits of trade discussed above start with increased R&D and innovation and lead to diffusion of better technology. But the adoption of new technology requires complementary skilled labor (Basu and Weil, 1998; Acemoglu and Zilibotti, 2001). The stock of and investment in human capital is often low in developing countries, which constrains technology adoption. Often, these developing countries end up specializing in the production of unsophisticated products that have limited prospects for revolutionary innovations, technology spillovers and productivity growth; thus, trapping them at low levels of income.

More formally, Young (1991) shows that industry-specific productivity advances are functions of not only the productive activity in that industry, but also of spillovers of learning-by-doing in other industries. Young (1991) ranks products hierarchically by the level of technological sophistication of the production process. Assuming learning-by-doing in production is bounded for every product by the level of technological sophistication of the production, he shows that the development of new productive technologies initially leads to rapid learning-by-doing. As the productive capacity of these new technologies is exhausted, and learning-by-doing slows down. To prevent the productivity advances from slowing down, new technical processes need to be introduced. In the absence of technological adoption, which in turn depends on complementary inputs, their static comparative advantage leads these economies to specialize in products in which gains from learning-by-doing have been largely exhausted. Countries with the prerequisite for technological diffusion, on the other hand, specialize in products in which learning-by-doing has strong momentum.

Along the same lines, Redding (1999) shows that the productivity gain may be short-lived for producers of unsophisticated goods with little promise of learning-by-doing. If producers fail to fully internalize the learning-by-doing potential of production relative to their trading partners, free trade will induce dynamic welfare losses for them. Hausmann et al. (2007) argue that poor countries tend not to gain from trade because entrepreneurs in these countries face considerable cost uncertainty when they plan to produce a new product. This deters them from undertaking the production of new products.

In related work, Matsuyama (1992) shows that a country in which the manufacturing sector is less productive than the agricultural sector specializes in agricultural production and deindustrializes over time. Globalization amplifies this effect by directing domestic demand for newer products to high-income elasticity sectors in rich countries (Matsuyama, 2019). Islam and Madsen (2018) argue that the agricultural sector cannot easily gain from knowledge spillovers via trade as agricultural knowledge tends to be specific to agro-climatic zones.

2.3 Effects on education and fertility

Galor and Mountford (2006, 2008) take the hierarchical model a step further by showing that countries with a comparative advantage in unskilled intensive agricultural production end up in a high-fertility regime with low investment in education, because the returns to education are low. Conversely, when a country with comparative advantages in skill-intensive production opens up for trade, the skill premium increases and the country moves up the QQ-schedule. Historically, since the industrial core countries specialized in production of relatively sophisticated products, the pre-WWI globalization wave promoted fertility transition in these countries, while the periphery countries were trapped in a high fertility regime (Galor and Mountford, 2008). Along the same lines, Williamson (2013) argues that the first globalization wave over the period 1850-1913 was a main factor behind the Great Divergence. The industrial core benefited from scale economies and specialization in manufacturing production while the periphery countries specialized in commodity production that resulted in deindustrialization, rent seeking, and excessive adverse income effects of marked commodity price volatility Williamson (2013).

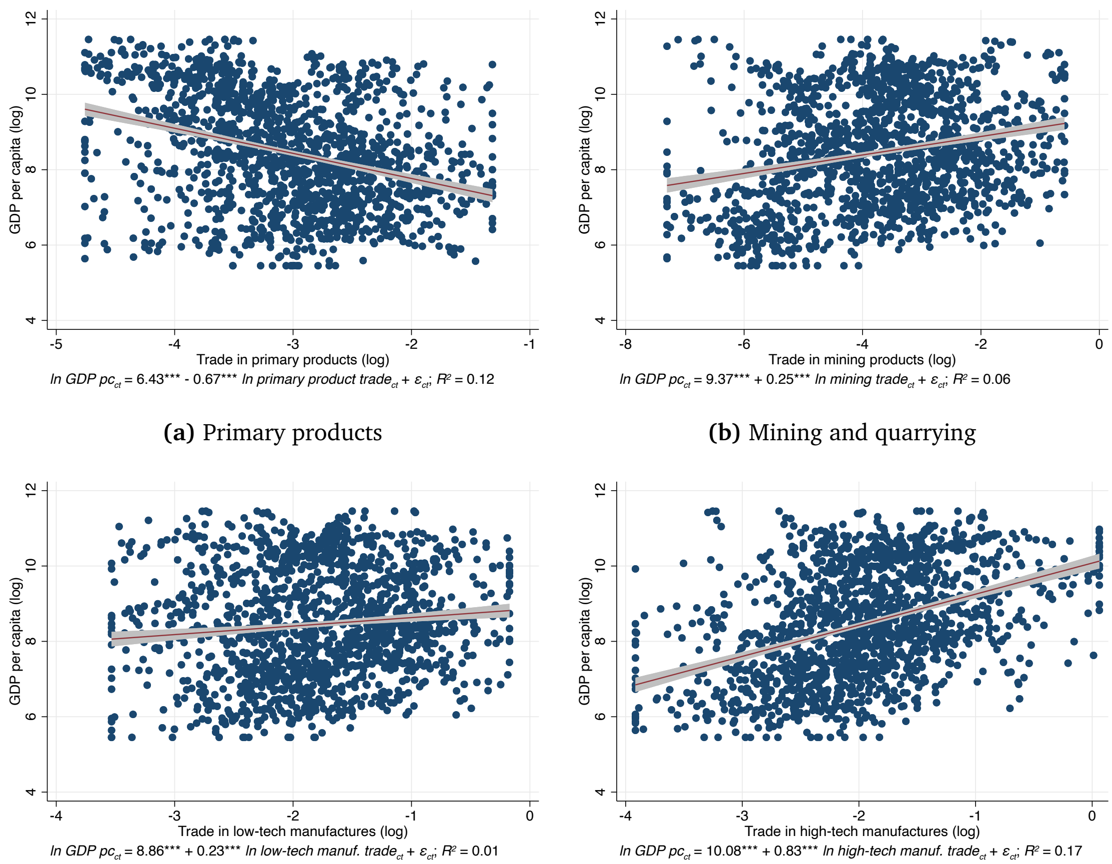
The Galor and Mountford (2006, 2008) model is complementary to the learning-by-doing model, essentially because of a direct positive link between the skill premium (returns to education) and technological sophistication of production. Another important feature of the Galor and Mountford (2006, 2008) model is the central role of the gender wage gap as well as the job opportunities and wages of females for the QQ-tradeoff decision. While the skill premium channel implies a positive relationship between technological sophistication and income, the nexus between women's relative wages and trade sophistication depends on the complementarity between women's employment opportunities and the production process. For example, the opportunities of females can be used as a potential explanation for why the New Industrialized countries escaped their low-income equilibrium (see Proposition 3 in Galor and Mountford (2008)). Starting from a low income level in the 1950s and 1960s, the emerging low-tech manufacturing production of textiles, standardized consumer goods, and food processing in East Asia, for example, increased the job opportunities for females relative to males. This, in turn, reduced the gender wage gap and the fertility. The reduced fertility gave increased opportunity for parents to invest more in each child, as predicted by the QQ-tradeoff framework. As shown theoretically and empirically by Madsen et al. (2020), the gender wage gap is influential for fertility and education by increasing the female opportunity costs of fertility.

2.4 Association between trade openness and per capita GDP

Figures 1-4 display the relationship between per capita GDP and the trade-income ratio by product categories in five-year averages for 98% of the winsorized data. The data sources and categorization procedure are detailed in the data section. Graphs with trade decomposed into imports and exports are presented in Appendix Figures A1 and A2. The association between trade in primary products and GDP per capita is negative, which is consistent to the discussion above that specialization in primary products offers limited potential for innovation and technology diffusion and little incentive to invest in human capital. The positive association trade in mining and quarrying products is somewhat surprising. The learning-by-doing prospects in mining are limited, and resource-rich countries have often been found to have poor institutions. However, as we show below in Appendix Table A3, the positive growth effects of specializing in mining disappears when we exclude the top oil-rich countries (oil exports accounting for more than 50% of total merchandise exports).

Trade in low-tech manufacturing products has a slight positive association with GDP per capita in the figure. Below, we show that the direction of this relationship becomes significantly negative once confounding variables and, particularly, unobserved heterogeneity are controlled for. Finally, Figure (1d) shows a positive association between trade in high-tech products and income that, we will see, is robust to a battery of checks. This is not surprising. High-tech products afford greater scope for technological diffusion, and could start a virtuous cycle of human capital formation and innovation; thus, promoting long-term growth.

Figure 1: Trade in different product categories and GDP per capita



(a) Primary products

(b) Mining and quarrying

(c) Low-technology manufactures

(d) High-technology manufactures

Sources: Bilateral SITC 3-digit level annual trade data from UN-COMTRADE database and GDP per capita, (constant 2010 USD) from World Bank (2020) for years 1962-2019.

3 Estimation strategy and data

3.1 Estimation strategy

Consider first the following model where income depends on trade openness in different product categories:

$$\begin{aligned}\ln Y_{it} = \alpha_0 + \alpha_1 \ln T_{it}^{HT} + \alpha_2 \ln T_{it}^{LT} + \alpha_3 \ln T_{it}^{MQ} + \alpha_4 \ln T_{it}^{PP} \\ + \alpha_5 \ln \text{Pop}_{it} + \alpha_6 \ln \text{Inst}_{it} + \beta \ln \mathbf{Z}_{it} + \kappa_r + \kappa_t + \epsilon_{it},\end{aligned} \tag{1}$$

where Y_{it} is income (GDP per capita) in country i in year t; T^{HT}, T^{LT}, T^{MQ}, and T^{PP} are high- and medium-tech (high-tech for shorthand) trade, low-tech and resource-based manufacturing (low-tech for shorthand) trade, mining and quarrying trade, and trade in primary products, as a share of GDP, respectively; **Z** is a vector of controls; κ_r and κ_t are region- and time-effects; and ϵ_{it} is the stochastic error term.

The regional dummies, κ_r, are based on the World Bank's classification that accounts for time-invariant differences across regions, such as distance from the equator and land size. We opt for regional effects in the baseline regressions because the variation in trade patterns, especially in the short to medium run, typically vary across, and not within, countries (See Table 2). Our results are consistent, although less efficient, when we replace region fixed effects with country fixed effects.

To simplify the exposition, we combine trade in high-tech and medium-tech manufacturing under the high-tech category. Medium-tech production processes, which include motor vehicles and machinery manufacturing, are sufficiently sophisticated to be classified as high-tech manufacturing products. Another simplification is the exclusion from Equation (1) of trade in miscellaneous goods, which make up only 1.3% of the GDP for an average country. However, we include trade in miscellaneous goods in total trade. In Appendix Table A2, we show that relaxing these two assumptions does not change our conclusions.

Following the literature on growth and trade, we use per capita income as the outcome variable. Total factor productivity, TFP, is not used as the regressand in the baseline regressions because 1) the available TFP estimates are limited to mostly high- and some middle-income countries, potentially introducing a country selection bias; 2) the existing estimates of TFP are highly problematic[1]; and 3) we want to capture the trade-effects on income through investment, education, labor force participation, efficiency, and technological progress; not only through the technology channel as implied by TFP-regressions. As shown and discussed in the Online Appendix, although the prin-

[1] In the absence of data on mining and land rent, the population growth drag is not factored out of the TFP estimates in the PWT. This implies that the primary product trade-induced population growth through the QQ-tradeoff channel increases TFP when the population growth drag is not allowed for in the TFP estimates; thus resulting in a significantly positive bias in the coefficients of agricultural trade elasticity. Furthermore, TFP is a highly problematic proxy for technology because capital accumulation is, to a large degree, driven by investment-specific technological progress that spurs capital accumulation by reducing the user cost of capital and, consequently, reduces TFP when in fact it should have increased TFP (Greenwood and Krusell, 2007).

cipal results are the same regardless of whether TFP or per capita income is used as the outcome variable, the economic effects are larger when income is used as the outcome variable (See Table A8).

As controls, we include immigration and FDI (foreign direct investment) to account for network integration effects. While important in their own right, the inclusion of these variables in the structural model will give an indication of whether the exclusion restriction is violated because the instruments for trade have captured immigration or FDI income-effects. For example, Ortega and Peri (2014) find that the income-effects of trade become insignificant once migration, instrumented with the Frankel-Romer geographic instruments, is accounted for. This suggests, the Frankel-Romer instruments capture the effects of immigration and, therefore, result in a violation of the exclusion restriction. FDI is included in the structural model as another network variable; however, it cannot be instrumented using bilateral instruments for our world sample since bilateral FDI flows are only available for the OECD countries and cover only a limited time span. As one of the few studies investigating the determinants of FDI from the gravity equation, Kahouli and Maktouf (2015) find that FDI is determined by factors that are quite different from the geographic determinants of bilateral trade used here.[2]

To reduce the influence of random and cyclical fluctuations, we follow the growth literature and estimate Eq. (1) using five-year non-overlapping observations even though this comes at the cost of a reduced sample size. In Appendix Table A6 we show that our results are robust to using semi-decennial, decennial or semi-centennial non-overlapping intervals. We log transform all variables to reduce the influence of outliers. Standard errors are clustered at the country level.

3.2 Identification

The coefficients of the trade variables included in Eq.(1) are unlikely to be unbiased. First, per capita income may affect the level and the composition of trade. For example, high-income countries are most likely to trade in high-tech products than low-income countries; thus, resulting in a positive feedback effect from income to high-tech trade. Second, the attenuation bias is likely to be large because of a significant misreporting in trade flows, as evidenced by large discrepancies in bilateral mirror flows, even when CIF/FOB factors are corrected for. Third, the coefficients of trade may be biased due to unobserved confounders that are correlated with trade.

As our primary identification strategy, we use a dynamic version of the Frankel and Romer (1999) IV strategy where bilateral trade levels, predicted from the gravity model, are used to instrument observed trade openness. The gravity theory of trade is modelled after the theory of gravitation from physics that includes the gravitational force between two bodies, F, can be

[2] Kahouli and Maktouf (2015), find that FDI is predominantly determined by inflation (negative) and internet users (positive) in the host country. Geographic distance and sharing a common border were either insignificant or had conflicting signs across their models. Furthermore, the coefficients of trade, shared language and colonial links were almost all insignificant.

expressed as $F = \mathbb{G}\frac{m_1 m_2}{r^2}$, where m_1 and m_2 are the masses of the interacting objects; r is the distance between the centers of the masses; and G is the gravitational constant. Adapted to trade, the theory suggests that the amount of trade between two countries should depend on the size of the two countries, which captures the size of the demand for different commodities, the distance between the two countries (transportation cost and familiarity), and other constant geographic and historical factors. Mathematically, $T_{ij} = \mathbb{T}\frac{s_i s_j}{d_{ij}^2}$, where s_i and s_j are relevant measures of the size of countries i and j; and d_{ij} is the distance between the two countries. Log-transforming this expression yields:

$$\ln T_{ij} = \ln \mathbb{T} + \ln s_i + \ln s_j + 2 \ln d_{ij}, \tag{2}$$

where we follow Frankel and Romer (1999) when choosing the geographic variables to empirically implement this gravity model for trade. We use the land areas and population sizes of the two trading countries as our measures for s_i and s_j, as factors affecting the demand, and sea and air distance between the two countries as our measure of the resistance to trade.[3] For $\mathbb{T}$, the constant factors that continue to have an impact on trade, we use whether the two trading countries are landlocked and whether they share a common land border (contiguity).

We estimate the following model separately for total exports, E, total imports, M, and total trade, T, (i.e., the sum of total exports and total imports) for each product category:

$$\begin{aligned}\ln\left(\tau_{ijt}^{k}/GDP_{it}\right) &= \beta_0 + \beta_t^N \ln N_{it} + \beta_t^A \ln A_{it} + \beta_t^{Ai} \ln D_{ij}^{Air} + \beta_t^S \ln D_{ij}^{Sea} + \beta_{2t}^N \ln N_{jt} + \beta_{2t}^A \ln A_j \\ &+ \beta_t^L (L_i + L_j) + \beta_t^B B_{ij} + \beta_t^{BAi} B_{ij} \ln D_{ij}^{Air} + \beta_t^{BSea} B_{ij} \ln D_{ij}^{Sea} + \beta_t^{BN} B_{ij} \ln N_{it} \\ &+ \beta_{2t}^{BN} B_{ij} \ln N_{jt} + \beta_t^{BA} B_{ij} A_{it} + \beta_{2t}^{BA} B_{ij} A_{jt} + \beta_t^{BL} B_{ij} (L_i + L_j) + \gamma_i + \gamma_j + \gamma_t + \varepsilon_{ijt}\end{aligned} \tag{3}$$

where GDP_{it} is nominal GDP of country i in year t; τ_{ijt}^{k} is the bilateral trade in product category k between country i and j; N_{it} and N_{jt} are the population sizes of country i and j; A_{it} and A_{jt} are land areas of country i and j; D_{ij}^{Sea} and D_{ij}^{Air}, are the sea distance and the great circle distance between country i and j; $\beta_t^L (L_i + L_j)$ takes the value of '2' if both trading partners are landlocked, '1' if only one of the two countries is landlocked, and '0' if none of the countries are landlocked. B_{ij} is a dummy variable that takes the value of one if the two trading countries share a common land border, and zero otherwise. γ_i, γ_j, and γ_t are reporter country, partner country, and time fixed effects. All nominal variables are denominated in USD.

We use the approach of Pascali (2017) and Feyrer (2019) by allowing the coefficients of the following time-invariant variables to vary over time: air and sea distance, land area, common border, and landlockedness. Sea distance and air distance are included in Eq. (3) to cater for 1) the increasing share of transport by air and a corresponding reduction in the share of sea transport

[3] Frankel and Romer (1999) use the great circle distance as a proxy for distance resistance. Pascali (2017) and Feyrer (2019) extend the model to include sea distance.

in total trade measured in values; and 2) the cross-country variation in transport mode depending on geographic distance, product composition of trade, and other geographic characteristics, such as ruggedness.

For the estimations of the gravity models, we use the Poisson Pseudo-Maximum-Likelihood (PPML) estimation technique (Silva and Tenreyro, 2006). Finally, the standard errors are clustered at the trading country pair level. In Online Appendix Table A5, we show that the results remain almost identical when we replace region or country fixed effects by country-pair fixed effects or by country-year fixed effects for both trading partners.

Our decision to interact the time-invariant geographic factors with time dummies, incorporates the empirical insights from various studies. Hummels (2007), for example, documents that the cost of air freight per ton fell by a factor of ten over the period 1955-2004, while ocean freight rates were generally flat over the 1952-1972 period and rose with oil prices through the 1980s. Feyrer (2019) points out that this led to an increase in air freight and a corresponding reduction in ocean freight, implying that the resistance to trade due to air and sea distances between countries changed over time. This change is likely to have affected trade across product categories differently. Mining and quarrying as well as primary products still continue to be transported via sea, while high-tech products are increasingly transported via air (see Feyrer (2019) for a detailed breakdown for the United States). Similarly, we allow the coefficients of land areas, landlockedness, and common border to vary over time due to oil price shocks, time-variation in communication and transport technology, etc.

To identify bilateral migration flows, we use cultural proximity between the two countries as instruments, following Bahar and Rapoport (2018). This is unlike Ortega and Peri (2014), who use geographical instruments for both trade and migration. We estimate the following gravity model for migration:

$$\begin{aligned}\ln\left(\text{Mig}_{ijt}/\text{Pop}_{it}\right) = \mu_{1t}(\text{Comcol})_{ij} + \mu_{2t}(\text{Colcol})_{ij} + \mu_{3t}(\text{Comrel})_{ij} + \mu_{4t}(\text{Oflang})_{ij} \\ +\mu_{2t}(\text{Splang})_{ij} + \mu_{6t}\ln N_{it} + \mu_{7t}\ln N_{jt} + \mu_r + \mu_j + \varepsilon_{ijt},\end{aligned} \tag{4}$$

where Mig_{ijt} migration is the stock of residents in country i born in country j; $(\text{ComCol})_{ij}$ indicates whether the two countries had at least one common colonizer in the past; $(\text{Colcol})_{ij}$ is a dummy taking the value of one if one of the countries was colonized by the other, and zero otherwise; $(\text{Comrel})_{ij}$ is a dummy variable taking the value of one for country pairs having at least one common religion; $(\text{OfLang})_{ij}$ is a dummy taking the value of one for country pairs having at least one common official language, and zero otherwise; $(\text{Splang})_{ij}$ is a dummy taking the value of one for country pairs having at least one common language spoken by at least 9% of the population, and zero otherwise.

Next, we use the predictions from Eq. (3) and Eq.(4) to construct the instruments for trade and immigration:

$$\hat{T}^k_{it} = \sum_{i \neq j} \exp^{\hat{\beta}' X^k_{ijt}}, \tag{5}$$

$$\hat{M}_{it} = \sum_{i \neq j} \exp^{\hat{\mu}' Z_{ijt}}, \tag{6}$$

where $\mathbf{X}_{ijt}$ and $\mathbf{Z}_{ijt}$ are vectors of right-hand side variables in Eq. (3) and Eq. (4).

3.3 Exclusion restrictions

A question is whether the exclusion restrictions for the instruments are plausibly satisfied. We check for any evidence against the validity of the exclusion restriction through the following steps:

First, as key growth transmitters through global interactions, we include immigration and FDI ratios in the second-stage regressions in the robustness section. If the coefficients of trade change significantly when these controls are included in the model, the exclusion restriction is violated because instrumented trade captures the impact of immigration and FDI on the outcome variable.

Second, in the robustness section, we estimate the baseline model in which out-of-sample bilateral trade relationships are used to form the instrument. In other words, the instrument for trade openness, Eq. (5), includes predictions for all potential bilateral trade relationships for our whole country sample. For example, if there is no reported trade in the technology group k between Congo and New Zealand, then a value of zero is entered into Eq. (5). In the out-of-sample predictions, the predicted values generated from the gravity model are included in the instrument. As shown by Deij et al. (2021), this gives consistent results regardless of whether the absence of reported trade is due to no trade, misreported data entry, or that the data are not published.

Why is it important to include out-of-sample predictions in the instrument set as a check for the exclusion restrictions? Deij et al. (2021) show that a serious violation of the exclusion restriction may occur if only observed bilateral trade relationships are used to form the trade instrument. They show that the coefficient of overall trade openness becomes significantly positive in a sample in which the bilateral trade flows are randomly generated when the instrument is generated from in-sample predictions. This is because the number of bilateral trade flows recorded in the data is a positive function of per capita income. Most bilateral trade flows in poor countries, for example, are either missing, misreported, or zero, while the reverse is true for advanced countries; thus, artificially creating an instrument for trade openness that is increasing in income regardless of whether such relationship exists.

Third, we estimate the immigration gravity model using the same geographic characteristics as instruments for migration as we use for trade to check the extent to which migration and trade are determined by the same geographic characteristics. Coefficient similarity between the two models indicates potential violations of the exclusion restrictions for both instruments because it increases the likelihood that bilateral flows of any type are captured by common geographic characteristics.

Fourth, we use several implicit checks of the plausibility of the exclusion restriction in the estimates below. For example, if the IV estimates of the fertility and the education models are consistent with those of the income-regressions, then it is more likely that the instruments are not capturing non-trade related effects on income, fertility and education because these variables are largely determined by the same factors. Furthermore, in the North-South trade section, we check whether the baseline results are determined by the identity of the country rather than production specialization. To this end, we estimate the baseline model for the South-South and South-all trade. If the results for the South are consistent with the baseline regressions, then this is evidence against the possibility that the instruments are correlated with unobserved factors that simultaneously determine income and trade.

3.4 Data

We use annual bilateral trade data from 1962 to 2019 from the UN-COMTRADE database, classified using the Standard International Trade Classification (SITC).[4] We then categorize each SITC product code into one of the following five categories: high-tech manufacturing (HT), low-tech manufacturing (LT), mining and quarrying products (MQ), primary products (PP), and miscellaneous products (MS). To achieve this, we follow the United Nations classifications of products based on R&D intensity (see Lall (2000) for documentation). This classification based on SITC revision 2 closely follows ISIC Revision 3 technology intensity definition (OECD, 2003).

Table 1: Examples of traded goods by degree of technological sophistication

1. Primary Commodities (PP) - Examples	**3. Low-tech Products (LT)- Examples**
Live animals for food Fresh or frozen meat Milk and cream Fresh and preserved eggs, birds Fresh, chilled, and frozen fish	Agro-based manufacturing: preserved or prepared meat, fish, vegetables Other-resource based manufacturing: metal ores, glass, clay refractory Low-tech manufacturing:textile, garment, footwear, handbags,paper, glassware, pottery, rails, iron and steel castings, toys, sporting goods, musical instruments
2. Mining and Quarrying (M&Q) - Examples	**4. High-tech Products (HT) - Examples**
Crude petroleum Lignite and peat coal Chemicals excluding pharmaceuticals Natural and manufactured gas Silver, platinum, nickel, aluminium, lead, zinc	Medium-tech: motor vehicle excluding buses, lorries, and special motor vehicles, synthetic fibres, railway coaches, explosives, steam boilers, internal combustion piston engines High-tech: radioactive materials, pharmaceutical products, steam engines, turbines, aircraft, optical instruments, television receivers, data processing machine parts

Notes: The classification follows Lall (2000). Please refer to Appendix Table A1 for details on the SITC product codes included in each category.

Table 1 presents some examples of the commodities included in each category. The complete classification is reported in Table A1. The classification is intuitive and shows the pyramid of the sophistication of the products. High-tech goods require large amounts of highly specialized and skilled labor. In comparison, production of low-tech goods, like textiles, toys, footwear, and processed food, can be done almost entirely with unskilled labor.

[4]The data available from the UN-COMTRADE database used SITC revision 1 codes from 1962 to 1975 and SITC revision 2 codes from 1976 to 2019. We convert data from all years into SITC revision 2 codes before splicing them.

Table 2: Summary statistics of the key variables (223 countries, 1962-2019)

Variables	Obs.	Mean	Std. Dev. (overall)	Std. Dev. (between)	Std. Dev. (within)
Total trade as a % of GDP	2,673	0.339	0.419	0.297	0.298
Trade in primary products as % of GDP	2,673	0.040	0.055	0.038	0.040
Trade in mining products as % of GDP	2,673	0.040	0.129	0.068	0.108
Trade in low-tech manufacturing as % of GDP	2,673	0.132	0.169	0.115	0.124
Trade in high-tech manufacturing as % of GDP	2,673	0.115	0.181	0.136	0.119
Trade in miscellaneous products as % of GDP	2,673	0.013	0.032	0.018	0.027
Total imports as a % of GDP	2,673	0.196	0.234	0.160	0.173
Import of primary products as % of GDP	2,673	0.017	0.024	0.016	0.019
Import of mining products as % of GDP	2,673	0.014	0.067	0.026	0.061
Import of low-tech manufacturing as % of GDP	2,673	0.078	0.094	0.062	0.071
Import of high-tech manufacturing as % of GDP	2,673	0.080	0.101	0.073	0.071
Import of miscellaneous products as % of GDP	2,673	0.006	0.017	0.008	0.015
Total exports as a % of GDP	2,673	0.143	0.207	0.150	0.143
Export of primary products as % of GDP	2,673	0.022	0.040	0.029	0.027
Export of mining products as % of GDP	2,673	0.026	0.093	0.062	0.069
Export of low-tech manufacturing as % of GDP	2,673	0.054	0.092	0.062	0.067
Export of high-tech manufacturing as % of GDP	2,673	0.034	0.091	0.069	0.057
Export of miscellaneous products as % of GDP	2,673	0.006	0.022	0.013	0.018
Level of executive constraint (0-1)	1,966	0.545	0.309	0.283	0.133
Total factor productivity (TFP)	1,252	0.979	0.348	0.242	0.253
Weighted Gross Enrollment Rate (GER)	1,426	22.107	7.217	6.280	3.681
Total Fertility Rate (TFR)	2,391	3.820	1.979	1.655	1.108
Net Foreign Direct Investment flows (USD millions)	1,944	4,710	2,350	1,380	1,860
Migrated pop/population as %	1,129	0.073	0.117	0.107	0.045
GDP per capita, (constant 2010 USD)	1,992	12,396	20,021	20,830	6,681
Population ('000) in reporting economy	2,596	25,300	106,000	102,000	26,400
GDP (USD millions, current)	2,096	189,000	1,000,000	685,000	669,000

Notes: The summary statistics calculation uses non-overlapping 5-year average of the variables listed.

The data on GDP at current prices in USD, GDP per capita (constant 2010 USD), weighted gross enrollment rate (GER), population, GDP growth, consumer price index, official exchange rate (LCU per USD, period average), and the total fertility rate are from the World Development Indicators (World Bank, 2020). The total fertility rate is the total number of children that would be born to a woman if she were to live untill the end of her child-bearing age and give birth to children in alignment with the prevailing age-specific fertility rates. Information on land area and bilateral air distances are from the CEPII database (Conte and Mayer, 2021). Information on sea distance is obtained from the CERDI Sea Distance Database that contains bilateral maritime distances between 227 countries (Bertoli et al., 2016).

As a proxy for institutional quality, we use the $v2x\_jucon$ variable from the V-Dem database, which measures the extent to which the executive respects the constitution and complies with court rulings. Measured on a continuous scale between 0 and 1, '0' denotes the least respect for the constitution and court rulings while '1' denotes the highest level of respect. The advantages of using the V-Dem database over other comparable data, is that it has the largest country coverage of the available institutional quality indicators and, more importantly, $v2x\_jucon$ is based on detailed analyses by a number of experts with knowledge of the institutional landscape of individual countries. Information on bilateral migration and country-level FDI are also sourced from World Bank (2020). Table 2 reports the summary statistics for the variables used.

4 Results

In this section we present OLS and IV regression results as well as estimates with categorized trade shares. Only the qualitative results are discussed in this section. The economic effects are summarized and discussed in Section 8.

4.1 OLS regressions

Table 3 presents the income regressions using OLS. The association of income with total trade, total imports, and total exports is reported in Columns (1), (3), and (5). The overall association is weak: The positive association between exports and income is counterbalanced by the negative correlation between income and imports. When trade is decomposed by the degree of sophistication, the coefficients of imports and exports of primary products are significantly negative, particularly for exports, suggesting a negative specialization effect, as measured by net exports, and low learning-by-doing opportunities for primary products.[5]

The coefficient of total mining trade is significantly positive, driven by significantly positive income effects of exports, while imports of mining products have no significant income effects. This finding does not necessarily invalidate the resource-curse hypothesis of negative income effects of mining exports. When the top oil producing countries are excluded from the sample, the significant positive association between mining exports and income disappears (Table A3), suggesting that the results in Table 3 are driven by the rich oil-producing countries.

For low-tech manufacturing products, there is a significant negative association between trade in low-tech manufacturing products and income. From this result, it is tempting to conclude that trade in low-tech manufacturing products is bad for growth and economic development. However, this is not necessarily the case. For low-tech imports, the coefficient is significantly more negative than that of exports, suggesting significant positive income-effects of net exports of low-tech products. But when imported, low-tech goods, such as textiles, are unlikely to promote productivity growth because they do not enter the production process as productivity-enhancing intermediate goods so they do not have any positive technological externalities. Instead, imports of low-tech manufacturing products crowd out female-intensive low-tech production. This, in turn promotes fertility because it crowds out domestic low-tech manufacturing that consists predominantly of textile and food processing; industries that are traditionally highly female labor intensive (see, e.g., Galor and Weil, 1996; Galor, 2022). For example, Moon (2019) finds that the increasing job opportunities in the low-tech sector has been the main driver of the almost three-fold increase in the female labor force participation rate in Bangladesh over the period 1991-2016. Since the full income-effects of fertility transitions take several decades to materialize (Madsen et al., 2020),

[5] The significantly negative income-effects of specialization in primary products, may partly explain why the Latin American countries, with a markedly high share of primary product exports in total income, have experienced incredibly low growth during the last century.

Table 3: The effect of trade on GDP per capita, by product category (OLS estimates, 1962-2019)

	(1)	(2)	(3)	(4)	(5)	(6)
	Ln(Real GDP per capita)					
	Total Trade		Imports		Exports	
Ln T^{TT}	0.041		-0.253*		0.184**	
	(0.113)		(0.145)		(0.072)	
Ln T^{PP}		-0.569***		-0.153*		-0.283***
		(0.083)		(0.091)		(0.042)
Ln T^{MQ}		0.144***		0.044		0.071***
		(0.040)		(0.059)		(0.020)
Ln T^{LT}		-0.454***		-1.055***		-0.107**
		(0.155)		(0.152)		(0.054)
Ln T^{HT}		0.503***		0.745***		0.190***
		(0.162)		(0.200)		(0.035)
Ln(Population)	-0.050	-0.211***	-0.111*	-0.255***	-0.046	-0.126***
	(0.050)	(0.046)	(0.057)	(0.057)	(0.049)	(0.040)
Institutional Quality	1.602***	1.589***	1.621***	1.592***	1.581***	1.464***
	(0.248)	(0.211)	(0.238)	(0.215)	(0.248)	(0.216)
R-squared	0.589	0.705	0.598	0.664	0.605	0.705
Mean of DV	8.37	8.37	8.38	8.38	8.37	8.39
# of countries	168	168	168	168	168	168
Observations	1,415	1,413	1,405	1,403	1,404	1,375

Notes: *,**,*** denote 10%, 5%, and 1% levels of significance, respectively. Robust standard errors, in parentheses, are clustered at the country level. All trade and income variables are five-year non-overlapping averages. All specifications control for year and region fixed effects.

most of the income-effects derived from the estimates in Table 3 are likely to reflect the productivity gains associated with the transition from agriculture to low-tech manufacturing.

For high-tech products, both imports and exports have significantly positive income effects, suggesting that it is overall trade that matters for income, not specialization effects, because of the positive technological externalities. High-tech imports, such as instruments and sophisticated machinery and equipment, increase the production potential directly through three channels: Production chains; investment in machinery and equipment that is more productive than the existing capital stock; and technology diffusion that increases the quality and the variety of the manufactured products. These strong income effects are consistent with the findings of Coe and Helpman (1995) and Madsen (2007). The positive income effects derived from high-tech export, are likely derive from positive learning-by-doing effects, scale effects, and an increasing production share of high-value-added, high-tech manufactures.

Turning to the control variables, as expected, the coefficients of institutional quality are all significantly positive. The reverse is true for population, indicating a population growth drag due to a dilution of capital per capita and diminishing returns introduced by land as a fixed factor of production. It could also be that an increase in population reduces trade openness because of a larger domestic market.

In sum, the estimates from Table 3 suggest that per capita income is not strongly correlated with the overall trade openness because conflicting growth effects of trade in different product categories counterbalance each other. It is the composition of trade and the trade-intensity in each product category that matters for income, not the overall trade openness. For high-tech products, imports as well as exports have positive income effects, while positive specialization effects derive from low-tech trade. For mining and primary products, the income effects derive from exports while the income effects of imports are negligible.

4.2 IV regressions

Before turning to the second-stage estimates for Equation (1), we present the the estimation results from the gravity models for trade and immigration with the intention to gain insights into the plausibility of the exclusion restrictions.

4.2.1 Gravity models

The focus parameters of the estimates of the gravity model for categorized trade openness and immigration are presented in Table 4. First, consider the estimates of the trade models. As predicted by theory, the coefficients of air (great circle) distance are significantly negative regardless of time-period and product type. The air distance elasticity of trade has increasingly become negative for manufacturing products over time, a result that is consistent with the finding of Feyrer (2019). The increasingly negative magnitude of the coefficient of air distance for manufacturing products, however, does not necessarily mean that the air transport costs have increased over time. Instead, an increasing utility of fast delivery may have increased the tendency to trade with countries in close vicinity as part of the value chain and, more likely, that use of air transportation has increased disproportionately more over short than long distances. While the air distance resistance has increased over time for manufacturing products, there is no significant trend in T^{PP} and T^{MQ}, which is unsurprising since air transport is not a realistic option for most of these products. Although fresh fruit and some vegetables are increasingly transported by air, the dominant agricultural trade commodities still have a low ratio of value-added to weight, such as cereals, wine, livestock, long-life dairy products, and frozen meat.

Table 4: Gravity estimates for trade and immigration

	(1)	(2)	(3)	(4)	(5)	(6)		(7)
	[...] trade as % of GDP							Mig/pop
	TT	*PP*	*MQ*	*LT*	*HT*	*MS*		
Ln $D_{ij}^{Air}\times$ I(1962-1967)	-0.892***	-0.852***	-1.181***	-0.852***	-0.774***	-1.353***	Comcol × I(1962-1970)	1.634***
	(0.098)	(0.115)	(0.271)	(0.121)	(0.109)	(0.189)		(0.219)
Ln $D_{ij}^{Air}\times$ I(1968-1972)	-1.069***	-0.795***	-1.738***	-0.999***	-0.784***	-1.460***	Comcol × I(1971-1980)	1.720***
	(0.102)	(0.102)	(0.269)	(0.101)	(0.104)	(0.260)		(0.232)
Ln $D_{ij}^{Air}\times$ I(1973-1977)	-0.864***	-0.897***	-0.386	-0.951***	-0.837***	-1.306***	Comcol × I(1981-1990)	1.800***
	(0.095)	(0.101)	(0.293)	(0.104)	(0.093)	(0.217)		(0.206)
Ln $D_{ij}^{Air}\times$ I(1978-1982)	-0.872***	-0.946***	-0.392	-0.978***	-0.799***	-1.076***	Comcol × I(1991-2000)	1.792***
	(0.086)	(0.146)	(0.211)	(0.113)	(0.086)	(0.297)		(0.201)
Ln $D_{ij}^{Air}\times$ I(1983-1987)	-0.947***	-0.685***	-0.636**	-1.167***	-0.920***	-1.070***	Comcol × I(2001-2010)	1.653***
	(0.073)	(0.133)	(0.223)	(0.091)	(0.073)	(0.230)		(0.198)
Ln $D_{ij}^{Air}\times$ I(1988-1992)	-0.869***	-0.640***	-0.439**	-1.061***	-0.799***	-1.397***	Oflang × I(1962-1970)	1.082***
	(0.072)	(0.113)	(0.153)	(0.092)	(0.067)	(0.248)		(0.291)
Ln $D_{ij}^{Air}\times$ I(1993-1997)	-0.962***	-0.765***	-0.741**	-1.099***	-0.873***	-1.213***	Oflang × I(1971-1980)	0.928***
	(0.066)	(0.085)	(0.227)	(0.080)	(0.059)	(0.165)		(0.274)
Ln $D_{ij}^{Air}\times$ I(1998-2002)	-1.070***	-0.900***	-0.723***	-1.219***	-1.027***	-1.182***	Oflang × I(1981-1990)	0.798**
	(0.057)	(0.081)	(0.144)	(0.068)	(0.063)	(0.147)		(0.247)
Ln $D_{ij}^{Air}\times$ I(2003-2007)	-1.082***	-0.871***	-0.561***	-1.177***	-1.148***	-0.942***	Oflang × I(1991-2000)	0.637**
	(0.051)	(0.074)	(0.117)	(0.068)	(0.054)	(0.140)		(0.229)
Ln $D_{ij}^{Air}\times$ I(2008-2012)	-1.092***	-0.880***	-0.647***	-1.212***	-1.153***	-1.079***	Oflang × I(2001-2010)	0.732**
	(0.051)	(0.069)	(0.118)	(0.068)	(0.050)	(0.145)		(0.241)
Ln $D_{ij}^{Air}\times$ I(2013-2017)	-1.194***	-0.966***	-0.887***	-1.288***	-1.226***	-1.255***	Comrel × I(1962-1970)	2.757***
	(0.057)	(0.069)	(0.177)	(0.072)	(0.052)	(0.139)		(0.300)
Ln $D_{ij}^{Air}\times$ I(2018-2019)	-1.224***	-0.924***	-0.921***	-1.298***	-1.276***	-1.271***	Comrel× I(1971-1980)	3.143***
	(0.057)	(0.076)	(0.178)	(0.071)	(0.055)	(0.137)		(0.309)
Ln $D_{ij}^{Sea}\times$ I(1962-1967)	-0.101	-0.100	0.255	-0.168	-0.193	0.132	Comrel× I(1981-1990)	3.159***
	(0.086)	(0.086)	(0.249)	(0.102)	(0.104)	(0.181)		(0.265)
Ln $D_{ij}^{Sea}\times$I(1968-1972)	0.065	-0.177*	0.971**	-0.101	-0.120	0.142	Comrel× I(1991-2000)	3.196***
	(0.097)	(0.084)	(0.314)	(0.087)	(0.090)	(0.188)		(0.260)
Ln $D_{ij}^{Sea}\times$ I(1973-1977)	-0.180	-0.105	-0.236	-0.289*	-0.144	0.050	Comrel × I(2001-2010)	2.884***
	(0.113)	(0.083)	(0.238)	(0.126)	(0.081)	(0.158)		(0.275)
Ln $D_{ij}^{Sea}\times$ I(1978-1982)	-0.168*	-0.103	-0.463**	-0.144	-0.121	-0.018	Splang × I(1962-1970)	1.199***
	(0.068)	(0.095)	(0.161)	(0.086)	(0.072)	(0.238)		(0.297)
Ln $D_{ij}^{Sea}\times$ I(1983-1987)	-0.117	-0.219	-0.483**	0.024	-0.065	-0.093	Splang × I(1971-1980)	1.293***
	(0.061)	(0.113)	(0.161)	(0.077)	(0.059)	(0.178)		(0.275)
Ln $D_{ij}^{Sea}\times$ I(1988-1992)	-0.180**	-0.270**	-0.627***	-0.068	-0.168**	0.080	Splang × I(1981-1990)	1.223***
	(0.059)	(0.094)	(0.116)	(0.077)	(0.057)	(0.198)		(0.266)
Ln $D_{ij}^{Sea}\times$ I(1993-1997)	-0.179**	-0.250***	-0.348*	-0.163**	-0.162**	-0.111	Splang × I(1991-2000)	1.321***
	(0.055)	(0.072)	(0.168)	(0.063)	(0.053)	(0.109)		(0.252)
Ln $D_{ij}^{Sea}\times$ I(1998-2002)	-0.133**	-0.254***	-0.396***	-0.085	-0.091	-0.257*	Splang × I(2001-2010)	1.289***
	(0.045)	(0.065)	(0.108)	(0.051)	(0.053)	(0.128)		(0.264)
Ln $D_{ij}^{Sea}\times$ I(2003-2007)	-0.122**	-0.252***	-0.406***	-0.116*	-0.032	-0.397***	Colcol × I(1962-1970)	1.364***
	(0.040)	(0.058)	(0.098)	(0.050)	(0.041)	(0.101)		(0.221)
Ln $D_{ij}^{Sea}\times$ I(2008-2012)	-0.123**	-0.284***	-0.442***	-0.100*	-0.003	-0.245*	Colcol × I(1971-1980)	1.554***
	(0.040)	(0.053)	(0.092)	(0.050)	(0.039)	(0.110)		(0.248)
Ln $D_{ij}^{Sea}\times$ I(2013-2017)	-0.003	-0.181**	-0.241	-0.016	0.096*	-0.043	Colcol × I(1981-1990)	1.628***
	(0.046)	(0.055)	(0.137)	(0.055)	(0.044)	(0.113)		(0.223)
Ln $D_{ij}^{Sea}\times$ I(2018-2019)	0.030	-0.201**	-0.123	-0.016	0.134**	0.078	Colcol × I(1991-2000)	1.496***
	(0.047)	(0.065)	(0.153)	(0.054)	(0.046)	(0.127)		(0.221)
							Colcol × I(2001-2010)	1.286***
								(0.211)
R^2	0.56	0.41	0.27	0.47	0.72	0.30		0.44
# of country pairs	33,985	33,985	33,985	33,985	33,985	33,985		37,830
Observations	229,690	229,690	229,690	229,690	229,690	229,690		189,150

Notes: *,**,*** denote 10%, 5%, and 1% levels of significance, respectively. Robust standard errors, in parentheses, clustered at the country-pair level. All trade and income variables are five-year non-overlapping averages. All models include the log of population in the reporting country and the partner country. In addition to distance, the gravity regressions for trade include the following geographic variables: a dummy variable that takes the value of one if the reporter and the partner are landlocked, and zero otherwise; a dummy variable indicating whether two countries share a common border; land area of the two countries; and the interaction of these variables with year dummies. We also include reporter, partner, and year fixed effects.

Table 5: Gravity estimates for trade and immigration using only geographic variables

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	[...] product trade as % of GDP						**Mig/pop**
	TT	*PP*	*MQ*	*LT*	*HT*	*MS*	
Ln $D_{ij}^{Air}\times$ I(1962-1970)	-1.001***	-0.903***	-1.205***	-0.998***	-0.842***	-1.566***	-1.669***
Ln $D_{ij}^{Air}\times$ I(1971-1980)	-0.934***	-0.940***	-0.467	-0.991***	-0.859***	-1.467***	-1.892***
Ln $D_{ij}^{Air}\times$ I(1981-1990)	-1.021***	-0.813***	-0.466*	-1.196***	-1.033***	-1.664***	-1.865***
Ln $D_{ij}^{Air}\times$ I(1991-2000)	-1.060***	-0.867***	-0.767***	-1.199***	-1.019***	-1.387***	-1.926***
Ln $D_{ij}^{Air}\times$ I(2001-2010)	-1.147***	-0.909***	-0.558***	-1.271***	-1.249***	-1.260***	-1.846***
Ln $D_{ij}^{Sea}\times$ I(1962-1970)	-0.017	-0.081	0.273	-0.081	-0.112	0.235	-0.045
Ln $D_{ij}^{Sea}\times$ I(1971-1980)	-0.100	-0.044	-0.182	-0.232*	-0.094	0.256	-0.008
Ln $D_{ij}^{Sea}\times$ I(1981-1990)	-0.102	-0.200*	-0.574***	-0.002	-0.039	0.268	0.019
Ln $D_{ij}^{Sea}\times$ I(1991-2000)	-0.113*	-0.233***	-0.302*	-0.083	-0.084	-0.113	0.025
Ln $D_{ij}^{Sea}\times$ I(2001-2010)	-0.079	-0.247***	-0.445***	-0.059	0.048	-0.209	0.007
Ln $N_{it}\times$ I(1962-1970)	-0.027	-0.079	-0.140	-0.082	0.016	-0.208*	-0.530***
Ln $N_{it}\times$ I(1971-1980)	-0.044	-0.010	-0.252*	-0.067	-0.020	-0.198*	-0.554***
Ln $N_{it}\times$ I(1981-1990)	-0.045	0.012	-0.114	-0.062	-0.070	-0.137	-0.585***
Ln $N_{it}\times$ I(1991-2000)	-0.028	0.026	-0.029	-0.059	-0.044	-0.098	-0.590***
Ln $N_{it}\times$ I(2001-2010)	0.010	0.056	-0.016	-0.021	0.004	-0.160	-0.606***
Ln $N_{jt}\times$ I(1962-1970)	0.235*	0.308**	0.876***	-0.109	-0.581***	-0.180	0.263*
Ln $N_{jt}\times$ I(1971-1980)	0.232*	0.303**	0.985***	-0.134	-0.620***	-0.224	0.229*
Ln $N_{jt}\times$ I(1981-1990)	0.215*	0.269**	0.992***	-0.158	-0.610***	-0.199	0.269*
Ln $N_{jt}\times$ I(1991-2000)	0.231*	0.292**	0.963***	-0.108	-0.618***	-0.233	0.274*
Ln $N_{jt}\times$ I(2001-2010)	0.260**	0.336***	1.002***	-0.091	-0.577***	-0.216	0.274*
$(L_i+L_j)\times$ I(1962-1970)	-1.101	-1.771	0.270	-1.706	-1.297	-1.661	-4.113***
$(L_i+L_j)\times$ I(1971-1980)	-1.315	-1.599	-0.692	-1.773	-1.463	-2.034	-4.252***
$(L_i+L_j)\times$ I(1981-1990)	-1.289	-1.683	-0.592	-1.931	-1.522	-1.716	-4.202***
$(L_i+L_j)\times$ I(1991-2000)	-1.153	-1.320	-0.653	-1.693	-1.626	-0.940	-4.154***
$(L_i+L_j)\times$ I(2001-2010)	-1.140	-1.482	-0.396	-1.805	-1.562	-0.750	-4.290***
Border $\times$ I(1962-1970)	3.492**	4.569**	-9.306*	4.861***	6.307***	3.108	-0.858
Border $\times$ I(1971-1980)	1.994*	4.271***	-4.461*	2.059*	3.857**	2.263	-2.538
Border $\times$ I(1981-1990)	-0.577	1.696	-6.014**	0.374	0.850	0.966	-2.727
Border $\times$ I(1991-2000)	-0.124	1.398	-4.770*	0.470	1.241	-0.689	-2.978
Border $\times$ I(2001-2010)	-0.305	1.385	-4.694*	0.688	0.250	-0.627	-1.820
Border $\times$ Ln $D_{ij}^{Air}\times$ I(1962-1970)	-0.025	0.689**	2.757***	-0.573*	-0.862*	0.153	1.105***
Border $\times$ Ln $D_{ij}^{Air}\times$ I(1971-1980)	-0.503**	0.671**	-0.069	-0.549**	-0.686*	-0.987**	1.160**
Border $\times$ Ln $D_{ij}^{Air}\times$ I(1981-1990)	0.185	0.562*	0.161	0.285	0.261	-0.634	1.280***
Border $\times$ Ln $D_{ij}^{Air}\times$ I(1991-2000)	-0.096	0.123	-1.242*	-0.036	0.176	-0.842*	1.281***
Border $\times$ Ln $D_{ij}^{Air}\times$ I(2001-2010)	0.060	0.056	-1.499**	-0.008	0.587**	-0.728*	1.300***
Border $\times$ Ln $D_{ij}^{Sea}\times$ I(1962-1970)	0.072	0.050	-0.136	0.159	-0.012	-0.038	0.038
Border $\times$ Ln $D_{ij}^{Sea}\times$ I(1971-1980)	0.135	-0.100	-0.076	0.314*	0.192	0.019	-0.045
Border $\times$ Ln $D_{ij}^{Sea}\times$ I(1981-1990)	0.022	-0.079	0.287	-0.006	0.054	-0.087	0.027
Border $\times$ Ln $D_{ij}^{Sea}\times$ I(1991-2000)	0.042	0.074	0.204	0.077	-0.022	0.258	0.034
Border $\times$ Ln $D_{ij}^{Sea}\times$ I(2001-2010)	0.024	0.227*	0.390*	0.060	-0.130	0.268	0.129
Border $\times$ Ln $N_{it}\times$ I(1962-1970)	-0.106	-0.232***	-0.554***	-0.028	0.034	-0.019	-0.136
Border $\times$ Ln $N_{it}\times$ I(1971-1980)	0.071	-0.193***	0.142	0.043	0.094	0.281**	-0.022
Border $\times$ Ln $N_{it}\times$ I(1981-1990)	0.024	-0.094	0.003	-0.024	0.049	0.144	-0.085
Border $\times$ Ln $N_{it}\times$ I(1991-2000)	0.038	0.011	0.065	0.010	0.033	0.194	-0.088
Border $\times$ Ln $N_{it}\times$ I(2001-2010)	-0.006	-0.015	0.116	0.004	-0.063	0.159	-0.103
Border $\times$ Ln $N_{jt}\times$ I(1962-1970)	-0.019	-0.307***	-0.583**	0.105	0.398***	-0.168	-0.014
Border $\times$ Ln $N_{jt}\times$ I(1971-1980)	0.130*	-0.228***	-0.185	0.150*	0.348***	0.154	-0.004
Border $\times$ Ln $N_{jt}\times$ I(1981-1990)	0.091	-0.080	-0.232*	0.105	0.208	0.225	-0.023
Border $\times$ Ln $N_{jt}\times$ I(1991-2000)	0.200*	0.003	0.387	0.207**	0.294**	0.237	-0.014
Border $\times$ Ln $N_{jt}\times$ I(2001-2010)	0.184**	-0.005	0.380*	0.191**	0.292***	0.217	-0.138
Border $\times(L_i+L_j)\times$ I(1962-1970)	0.427*	1.320***	-0.138	0.618***	0.206	0.569	0.093
Border $\times(L_i+L_j)\times$ I(1971-1980)	0.870***	0.974***	1.853***	0.845***	0.204	1.279***	0.292
Border $\times(L_i+L_j)\times$ I(1981-1990)	0.945***	1.443***	1.573**	0.999***	0.304*	0.961*	-0.008
Border $\times(L_i+L_j)\times$ I(1991-2000)	0.748***	0.899***	0.951**	0.721***	0.600***	0.669**	-0.130
Border $\times(L_i+L_j)\times$ I(2001-2010)	0.680***	0.961***	0.933**	0.779***	0.523***	0.493	0.004
Border $\times$ Ln A_{it}	-0.111	-0.265***	-0.020	-0.070	-0.112	-0.253**	-0.130
Border $\times$ Ln A_{jt}	-0.017	0.103	0.357**	-0.110	-0.233***	0.202	-0.100
R^2	0.54	0.43	0.320	0.49	0.67	0.40	0.53
# of country pairs	32,420	32,420	32,420	32,420	32,420	32,420	39,284
Observations	95,237	95,237	95,237	95,237	95,237	95,237	196,420

Notes: *,**,*** denote 10%, 5%, and 1% levels of significance, respectively. Robust standard errors, clustered at the country-pair level, are not reported here for brevity, but available on request. All trade and income variables are measured in ten-year intervals for the sample period 1962-2010. We also include reporter, partner, and year fixed effects.

The coefficients of sea distance are all negative, but are significant only for T^{PP} and T^{MQ} over the periods 1988-2019 and 1978-2012, respectively. The statistical insignificance of the resistance terms for manufactured goods may indicate that the great circle distance (air distance) also captures the resistance associated with land transport via rail and trucks - a mode of transport used extensively for trade in manufacturing within Europe. Trade in high-tech goods is much more sensitive to air distance relative to sea distance compared to trade in primary products, low-tech goods and mining products. This is consistent with the data from the US. According to Feyrer (2019), the fraction of goods transported by air in 2001 was substantially higher for high value-to-weight products, such as pharmaceuticals, instruments, and electronics.

Turning to the estimates of the gravity model for immigration in the last column in Table 4, the coefficients of the dummies of the cultural variables are all significantly positive at the 1% level for all years, suggesting that close cultural links are important determinants of the destination country chosen by immigrants. Furthermore, there is no clear trend in the coefficients of the cultural variables.

To check for the validity of the exclusion restrictions of the instruments used for trade, we regress the gravity model for immigration using the same instruments as those used for trade (Table 5). Since immigration data are available at 10-year intervals over the period 1962-2010, we use similar interval data in all columns of Table 5. Although the sample size is slightly different from Table 4, the results are almost identical when only overlapping data are used.

Remarkably, the coefficients of trade and immigration are, except for great circle distance, close to being orthogonal. Since the number of coefficients of great circle distance make up less than 10% of the total number of coefficients, this result suggests that the lion's share of the identifying variation in the instrument for trade satisfy the exclusion restriction assuming that the partial correlation coefficients are the same. Complementary to this, the baseline IV results, which are presented in the next sub-section, remain almost unaltered if the baseline second-stage regressions are based on instruments in which the great circle distance is excluded from the gravity regression (see, Online Appendix Table A16). From these results, we can conclude that the exclusion restriction in the baseline trade model is unlikely to be violated due to immigration effects; i.e., that the instruments used in the baseline regressions capture immigration effects.

4.2.2 Second-stage regressions

The second-stage results are presented in Table 6. The Sanderson-Windmeijer *F*-tests for excluded instruments, derived from the first-stage results presented in the Online Appendix Table A4, are highly significant in all cases, suggesting that the relevance criteria is satisfied. For brevity, we report the lowest F-stat across all specifications in the notes to each of the 2SLS tables. Turning to the second-stage regressions, the principal results are consistent with our findings from the OLS regressions. The coefficients of high-tech goods, HT, are consistently significantly positive for total trade, imports and exports. Although the coefficients of low-tech manufacturing imports and exports are both significantly negative, the net specialization effect, as signified by net exports, is significantly positive. The negative income-effect from imports of low-tech manufactured products again indicates an associated crowding out effect on female-intensive manufacturing and the trickle-down effects on fertility, as shown below. Finally, the coefficient of exports of primary products is significantly negative while that of mining products is significantly positive.

Table 6: The effect of trade on GDP per capita, by product category (2SLS estimates, 1962-2019)

	(1)	(2)	(3)	(4)	(5)	(6)
	Ln(Real GDP per capita)					
	Total Trade		Imports		Exports	
Ln T^{TT}	0.098		-0.415*		0.304***	
	(0.175)		(0.230)		(0.110)	
Ln T^{PP}		-0.691***		-0.017		-0.332***
		(0.122)		(0.166)		(0.054)
Ln T^{MQ}		0.165***		0.022		0.094***
		(0.062)		(0.095)		(0.030)
Ln T^{LT}		-0.868***		-1.539***		-0.237***
		(0.191)		(0.259)		(0.081)
Ln T^{HT}		0.924***		0.984***		0.296***
		(0.160)		(0.311)		(0.059)
Ln(Population)	-0.049	-0.285***	-0.152***	-0.321***	-0.043	-0.168***
	(0.052)	(0.051)	(0.067)	(0.071)	(0.049)	(0.040)
Institutional Quality	1.594***	1.506***	1.628***	1.597***	1.553***	1.337***
	(0.254)	(0.213)	(0.235)	(0.220)	(0.257)	(0.234)
Mean of DV	8.38	8.38	8.38	8.38	8.38	8.40
# of countries	162	162	162	162	162	162
Observations	1,388	1,386	1,378	1,376	1,377	1,348

Notes: *,**,*** denote 10%, 5%, and 1% levels of significance, respectively. Robust standard errors, in parentheses, are clustered at the country level. All trade and income variables are five-year non-overlapping averages. All specifications control for year and region fixed effects. The first-stage F-stats for all excluded instruments are ≥ 165.28.

4.2.3 Why are the trade effects larger for 2SLS than OLS?

Based on the Frankel and Romer (1999) framework, the literature generally finds that the 2SLS coefficients for trade openness in the income regressions are significantly larger than the OLS estimates. This raises the possibility that the exclusion restriction is violated. Frankel and Romer (1999), for example, find the 2SLS coefficient of trade openness to be 226% higher than the OLS coefficients (from their Table 3, Columns (1) and (2)). In our estimates, the sum of the absolute value of the 2SLS coefficients of the four trade categories of imports (exports) are 28% (47%) higher than the OLS estimates, suggesting a markedly smaller discrepancy than that of Frankel and Romer (1999).

The 2SLS-OLS discrepancy in our estimates is likely to be caused by an attenuation bias in the

OLS estimates because misreporting in foreign trade is rampant due to mis-classification of products and country of origin/destination, tariff (tax) avoidance, smuggling, hording of foreign currency, etc. Farhad (2020), for example, estimates a lower bound of 30% in misreported world trade, suggesting a potentially large attenuation bias in the OLS estimates. Furthermore, the coefficients of trade openness are biased towards -1 because of the inverse relationship between the outcome variable (per capita income) and the denominator of trade openness.

4.3 Trade shares on categories and growth

In this section, we report the income effects of the trade share of each product category in total trade instead of using the share of trade in total income as regressors. There are two reasons for using distribution of trade shares as regressors. First, the coefficients of product-type trade shares are relatively shielded from feed-back effects if the exclusion restriction in the IV-estimates is violated. If the exclusion restriction in the baseline regressions is violated, we would expect the principal results in this subsection to differ from the baseline results, since the distribution of trade on product categories is determined by geographic characteristics that differ from product-type trade openness in the gravity model estimates. Second, the trade-share estimates provide direct information on the income effects of a mean-preserved switch from one type of trade to another.

Table 7: The effects of changes in trade composition on GDP per capita (1962-2019) using 2SLS estimation

	(1)	(2)	(3)
	Ln(Real GDP per capita)		
	Total Trade	Imports	Exports
Ln T^{TT}	-0.361*	-0.543**	-0.145
	(0.184)	(0.248)	(0.119)
Ln(Share of T^{PP})	-0.693***	-0.494*	-0.334***
	(0.121)	(0.250)	(0.051)
Ln(Share of T^{MQ})	0.098	-0.106	0.076*
	(0.091)	(0.121)	(0.045)
Ln(Share of T^{LT})	-1.007***	-2.902***	-0.276**
	(0.270)	(0.627)	(0.108)
Ln(Share of T^{HT})	0.726***	-0.315	0.241***
	(0.233)	(0.615)	(0.072)
Mean of DV	8.38	8.38	8.40
# of countries	162	162	162
Observations	1,387	1,377	1,349

Notes: *,**,*** denote 10%, 5%, and 1% levels of significance, respectively. Robust standard errors, in parentheses, are clustered at the country level. All trade and income variables are five-year non-overlapping averages. Share of each product category is calculated for total trade/imports/exports by dividing trade in each category by total trade value so that the shares add up to 100. Miscellaneous trade is not presented. All specifications control for year and region fixed effects. The first-stage F-stats for all excluded instruments are ≥ 90.40.

The sign and statistical significance of the trade share variables are approximately similar to those of the baseline estimates, suggesting that the exclusion restrictions in the IV baseline estimates are plausibly satisfied. Compared to the baseline regressions, the interpretation of the coefficients and their statistical significance are in relative terms instead of the usual absolute terms because it is a zero-sum game in which trade shares add to one. Therefore, the coefficients need to be interpreted in relative terms, i.e., the income effects of changing the composition of trade. To ensure that the shift from one to another product is mean-preserving, we need to use the semi-elasticities so the coefficients can be interpreted as percentage points.

Table 8: Income effects of a 1-percentage point switch in trade from one category to another

	Total Trade				Imports				Exports			
					From category							
To category	PP	MQ	LT	HT	PP	MQ	LT	HT	PP	MQ	LT	HT
PP	1				1				1			
MQ	4.87	1			5.28	1			1.95	1		
LT	2.30	-2.57	1		-2.01	-7.30	1		0.65	-1.30	1	
HT	7.13	2.26	4.83	1	5.28	0.00	7.30	1	2.58	0.62	1.93	1

Notes: The income effect for each category i is estimated as $\frac{\alpha^i}{share_i} - \frac{\alpha^j}{share_j}$, where $\alpha^i(\alpha^j)$ is the estimated effect of trade in product category $i(j)$ and $share_i$ and $share_j$ are the average shares of product categories i and j in total trade/imports/exports. The coefficients that are statistically insignificant are set to zero.

Table 8 presents the income effect of a decrease in the trade share of one category by a 1-percentage point, matched with an increase in the trade share of another category by 1-percentage point. In the estimates, statistically insignificant coefficients from Table 7 are set to zero. As expected, the income effects of increasing the share of high-tech products in total trade at the expense of any other product category, is associated with a positive income effect. An income effect of 7.3% obtains with a one-percentage point increase in the high-tech import share is matched by one percentage point reduction in the import share of low-tech products: High-tech imports result in positive knowledge spillovers while the reduction in low-tech imports increases domestic production of low-tech female-intensive products.

Since many countries cannot easily make a switch to high-tech production, a realistic alternative is to switch from specialization in primary production to specialization in low-tech production. If this results in a one-percentage point shift in 1) exports of primary to low-tech products; and 2) a reverse swap in imports from low-tech to primary products, then income increases by 0.65% + 2.01% = 2.66%. Since the low-tech sector predominantly uses unskilled labor and the labor supply from the agricultural sector in many poor countries is elastic, a large boost in low-tech production is not only feasible, it also has large income effects - not least because the marginal productivity of agricultural labor tends to be low in poor countries.

5 Growth effects of trade

Thus far, we have assumed that learning-by-doing is static in nature, implying that a change in trade openness of product type k has a one-off permanent income effect. Numerous empirical studies have derived distinctive theoretical implications of the learning-by-doing effects of passive learning Thompson (2010). These studies find declining declining cost–quantity relationships over time as shown in (Thompson, 2010). If learning is dominantly passive, then productivity growth is invariably bounded and too much passive learning may, under certain circumstances, lead to stagnation (Thompson, 2010).

When a distinction between passive and active learning is made, trade in some types of products may have persistent or even permanent growth effects if they promote active learning, where active learning is a goal-direct activity, such as investment in R&D, and hence distinct from passive learning. The knowledge derived from R&D embodied in these products accumulate over time, continually pushing the TFP frontier outwards. In this section, we check whether there is active learning-by-doing that has persistent or permanent growth effects across product types.

To see how R&D and hence, potentially, trade in high-tech products feed into the growth process, consider the homogeneous Cobb–Douglas production function:

$$Y = AK^{\alpha}L^{1-\alpha},$$

where Y is output; A is the knowledge stock; K is capital; and L is labor. To find the dynamic income effects of trade in different types of goods categorized according to their R&D embodiment, consider the Romer (1990) ideas production function, extended to encompass the predictions of second-generation Schumpeterian growth models (see, e.g., Peretto, 1998; Ha and Howitt, 2007; Madsen, 2010). The growth in knowledge, g_A, is governed by the following ideas production function (Ha and Howitt, 2007; Madsen, 2010).

$$g_A = \dot{A}/A = \lambda(X/Q)^{\sigma}A^{\phi-1}, \qquad Q \propto L^{\beta}, \;\; 0 < \sigma \leqslant 1, \;\; \phi \leqslant 1, \tag{7}$$

where X is a measure of innovative activity, such as R&D and patents; Q is product variety; β is the coefficient of product proliferation; ϕ is returns to scale in knowledge; λ is a research productivity parameter; and σ is a duplication parameter, which is zero if all innovations are duplications and one in the absence of duplicated innovations.

The first-generation endogenous growth theory of Romer (1990) predicts that $\phi = 1$ and $\beta = 0$; Schumpeterian growth models predict that $\phi = 1$ and $\beta = 1$; and semi-endogenous growth models predict that $\phi < 1$ and $\beta = 0$. Innovative activity has permanent growth effects if $\phi = 1$. The productivity adjustment in Schumpeterian growth models recognises that innovations are increasing in complexity and, therefore, that there is a tendency for decreasing returns to R&D (Ha and Howitt, 2007). Henceforth, the ratio of X and Q will be referred to as research intensity.

Empirically, Ang and Madsen (2015) find that the null hypothesis of $\phi = 1$ and $\beta = 1$ cannot be rejected at conventional significance levels for the advanced countries.

Eq. (7) provides two important insights. First, assuming that $\beta = 1$, and that the complexity of new innovations is proportional to labor productivity, it is trade-intensity, T^k, and not trade volume, τ_{ijt}^k, that matters for per capita income growth. Second, T^k has permanent growth effects if it enhances the knowledge stock (level of technology) in the same fashion as R&D intensity by advancing the quality of final products and the technology embodied in intermediate inputs. The knowledge stock, A, increases permanently at a constant rate if ϕ is equal to one as assumed in first-generation endogenous growth models and Schumpeterian second generation growth models. Long-lasting growth effects result from TT^k (trade-intensity of product k) if ϕ is close to one.

According to the learning-by-doing model, high-tech trade is predicted to put productivity on an upward trajectory, a growth-effect that will be long-lasting or even permanent, depending on scale effects in the ideas production function. The growth-effects of specialization in low-tech manufacturing and agriculture, by contrast, are bounded. For countries in which the majority of the population is trapped in the Malthusian regime, an increase in trade in agricultural products leads to a one-off reduction in per capita income provided that per capita income exceeds subsistence, otherwise the effect is zero. If per capita income is pulled below the subsistence level by a trade-induced increase in fertility, the fertility rate subsequently declines and eases the population growth drag until the initial per capita income level is reestablished.

To check for the growth effects of various trade categories, we estimate the following two models:

$$\Delta \ln Y_{it} = a_0 \ln T_{it}^{HT} + a_1 \ln T_{it}^{LT} + a_2 \ln T_{it}^{MQ} + a_3 \ln T_{it}^{PP} + \Xi_{it}, \tag{8}$$

$$\ln Y_{it} = b_0 \ln Y_{i,t-1} + b_1 \ln T_{it}^{HT} + b_2 \ln T_{it}^{LT} + b_3 \ln T_{it}^{MQ} + b_4 \ln T_{it}^{PP} + \Xi_{it}, \tag{9}$$

where $\Xi_{it} = \alpha_4 \ln \text{Pop}_{it} + \alpha_5 \ln \text{Inst}_{it} + \Omega_{it}\zeta' + \kappa_r + \kappa_t + \epsilon_{it}$. Here, Eq. (8) tests for potential permanent growth-effects of trade for product category k, while Eq. (9) tests for persistent but not permanent growth-effects of trade for all product categories, jointly.

The results of estimating Equations (8) and (9) are presented in Table 9. In the first three columns where per capita income growth is the dependent variable, the coefficients of high-tech trade are all significantly positive, while the coefficients of the other trade variables are insignificant. These results are intuitive. Only trade in high-tech products has permanent growth effects because these products embody new technologies and are associated with or stimulate R&D through cut-throat competition and creative destruction. On the import side, the constant inflow of high-tech intermediate products that are superior to previous vintages, such as machinery, information and communication technology, improves the efficiency of the production process by delivering a flow of investment-specific technological progress that continually increases the efficiency of production. The significance of this channel in the growth process is evidenced by Greenwood and Krusell (2007), who find that investment-specific technological progress is responsible for approxi-

Table 9: The effect of trade in different categories on Δ real GDP per capita (1962-2019)

	(1)	(2)	(3)	(4)	(5)	(6)
	Δ Ln(Real GDP per capita)			**Ln(Real GDP per capita)**		
	Total Trade	Imports	Exports	Total Trade	Imports	Exports
Ln T^{PP}	-0.005	0.010	0.002	-0.025**	0.009	-0.008
	(0.010)	(0.014)	(0.005)	(0.011)	(0.014)	(0.005)
Ln T^{MQ}	-0.003	0.005	-0.003	0.002	0.005	-0.000
	(0.005)	(0.007)	(0.003)	(0.005)	(0.007)	(0.003)
Ln T^{LT}	0.023	-0.000	0.007	-0.003	-0.030	-0.000
	(0.016)	(0.023)	(0.008)	(0.020)	(0.026)	(0.009)
Ln T^{HT}	0.027*	0.039**	0.013**	0.055***	0.057***	0.022***
	(0.016)	(0.017)	(0.006)	(0.018)	(0.019)	(0.007)
Ln(Real GDP per capita$_{(t-1)}$)				0.970***	0.980***	0.970***
				(0.007)	(0.006)	(0.007)
Ln(Population)	0.012**	0.012**	0.004	0.003	0.006	-0.001
	(0.005)	(0.005)	(0.005)	(0.006)	(0.006)	(0.005)
Institutional Quality	0.000	0.006	-0.017	0.046*	0.037	0.024
	(0.022)	(0.022)	(0.025)	(0.025)	(0.025)	(0.026)
Mean of DV	0.09	0.09	0.09	8.41	8.41	8.43
# of countries	161	161	161	161	161	161
Observations	1,279	1,270	1,246	1,279	1,270	1,246

Notes: *,**,*** denote 10%, 5%, and 1% levels of significance, respectively. Robust standard errors, in parentheses, are clustered at the country level. All trade and income variables are five-year non-overlapping averages. All specifications control for year and region fixed effects. The first-stage F-stats for all excluded instruments are ≥ 293.83.

mately half of the technological progress in the US. Adding to this, measured from the expenditure side, imports of high-tech consumables and investment products enhance income as the products get cheaper.

High-tech exports may promote growth by allowing for scale effects in R&D though larger markets, increased sales of existing R&D intensive firms, international technology-diffusion, and creative destruction of low R&D intensive and unproductive firms (Grossman and Helpman, 1991; Rivera-Batiz and Romer, 1991). Quantitatively, a one-percentage point increase in high-tech imports (exports) is associated with a 0.49% (0.38%) increase in the growth rate, suggesting that trade in high-tech products is a significantly positive determinant of growth.

Overall, only high-tech trade openness promotes growth driven by exports as well as imports, as predicted by Schumpeterian learning-by-doing models. This result is also consistent with the Schumpeterian growth framework in which R&D is normalized with income to filter out the horizontal innovations (product variety) of R&D (see, e.g., Peretto, 1998; Ha and Howitt, 2007).

Next, consider the results in Columns (4) and (6), where the dependent variable (per capita income) is lagged one period (five years). The coefficients of high-tech exports and imports are again significantly positive and the coefficients of lagged income are 0.98 (imports) and 0.97 (exports), suggesting that high-tech trade has highly persistent income effects but, statistically, non-permanent growth effects; however, since the lagged coefficient is biased downward due to the Nickel bias, we cannot conclude that the coefficient of lagged income is significantly below one. More importantly, since the model imposes the same adjustment lag structure on all the regressors, the coefficients of lagged income are dragged down by the short-term income effects of the non-high-tech variables.

The coefficients of the non-high-tech variables, population and, to a large extent, institutions on total trade, are insignificant. This does not mean that income is unaffected by these variables, but that they do not have persistent income effects. In fact, a lagged dependent variable specification is a problematic specification in most situations (Keele and Kelly, 2006). If residual serial correlation is present, as here, the lagged dependent variable causes the coefficients of explanatory variables to be biased towards zero. In other words, a lagged dependent variable that is trended, renders the coefficient estimates insignificant in most circumstances.

Finally, the estimates in this section give credibility to our identification strategy. Had instrumented trade captured non-trade externalities stemming from migration and FDI, then it is highly unlikely that we would have found permanent growth effects of only high-tech trade since it is inconceivable that the average migrant or average unit of FDI have permanent growth effects.

6 Robustness tests

In this section we undertake robustness tests 1) to ensure that the exclusion restriction is plausibly satisfied; and 2) to check whether the baseline results are driven by unobserved cross-country heterogeneity. Additionally, in the Online Appendix it is shown that the results are robust to the inclusion of country-pair or bilateral country-year fixed effects in the gravity estimates (Table A5).

6.1 Controlling for immigration and FDI

As argued in Section 3, immigration and FDI are potentially important confounders because, together with trade, they represent international networks of knowledge externalities. Ortega and Peri (2014), for example, find that overall merchandise trade openness loses its significance once migration is included in the structural regression, while Bahar and Rapoport (2018) find positive productivity spillover effects from migration; however, they do not include trade openness in their structural model. Omission of immigration and FDI from the trade model may lead to an omitted variable bias that potentially stems from the violation of the exclusion restriction.

Table 10 displays the results from the baseline model extended with immigration and FDI (Columns (4)-(6)). For comparative purposes, we reproduce the results from the baseline specification with this smaller sample in Columns (1)-(3), since the bilateral migration flows are available for a slightly smaller set of countries than trade and a shorter time span than the baseline. When FDI and immigration are controlled for in columns (4)-(6), the parameter estimates of the trade variables are close to those of the baseline regressions in the first three columns. We obtain similar results if the Frankel-Romer instruments are used for immigration instead of the cultural instruments, as shown in Appendix Table A14. These results suggest that the trade variables in the baseline regressions are not capturing the income-effects of immigration or FDI flows. In other words, these results do not give any evidence against exclusion restriction in the baseline IV regressions in the sense that the geography-specific instruments are not capturing the income-effects of immigration. These results corroborates our findings in Section 4.2.1 where it is shown that the geographic determinants of trade and immigration are dissimilar. Turning to the new confounders, the coefficients of immigration are significantly positive, the coefficients of FDI are insignificant, and the coefficients of the distance from the equator are positive but generally not significant. When going from aggregate to decomposed trade openness, the coefficients of immigration drop by 30%, on average (Appendix Table A14), suggesting that decomposed trade is an important control variable when the economic effects of immigration are assessed. To put the relative importance of immigration and trade into perspective, a one standard deviation increase in high-tech (low-tech) trade results in a 14.4% (12.5%) increase in income, while for immigration, the income effect is 2.2%.

Table 10: 2SLS estimates of trade and immigration (1962-2010)

	(1)	(2)	(3)	(4)	(5)	(6)
	Ln(Real GDP per capita)					
	w/o FDI and Migration controls			**with FDI and Migration controls**		
	Total Trade	Imports	Exports	Total Trade	Imports	Exports
	Panel A: All products					
Ln T^{TT}	0.142	-0.32	0.301***	0.089	-0.349**	0.221**
	(0.174)	(0.223)	(0.115)	(0.140)	(0.174)	(0.103)
Ln(FDI/GDP)				-0.011	0.055	-0.038
				(0.059)	(0.061)	(0.064)
Ln(Immigration)				0.310***	0.315***	0.294***
				(0.062)	(0.062)	(0.063)
Mean of DV	8.21	8.22	8.22	8.22	8.23	8.23
# of countries	161	161	161	159	159	159
Observations	590	585	586	555	551	552
	Panel B: By product categories					
Ln T^{PP}	-0.715***	0.108	-0.323***	-0.650***	0.221	-0.302***
	(0.114)	(0.183)	(0.056)	(0.119)	(0.176)	(0.059)
Ln T^{MQ}	0.188***	-0.088	0.104***	0.154**	-0.125	0.083**
	(0.066)	(0.112)	(0.033)	(0.064)	(0.102)	(0.033)
Ln T^{LT}	-0.801***	-1.998***	-0.198**	-0.739***	-1.811***	-0.175**
	(0.162)	(0.367)	(0.081)	(0.174)	(0.343)	(0.080)
Ln T^{HT}	0.933***	1.690***	0.263***	0.795***	1.451***	0.186***
	(0.162)	(0.421)	(0.061)	(0.155)	(0.366)	(0.062)
Ln(FDI/GDP)				0.050	0.018	0.035
				(0.056)	(0.072)	(0.050)
Ln(Immigration)				0.187***	0.240***	0.204***
				(0.055)	(0.057)	(0.054)
Ln(Distance from equator)				0.010	0.015**	0.008
				(0.006)	(0.007)	(0.007)
Mean of DV	8.21	8.22	8.24	8.22	8.23	8.25
# of countries	161	161	160	159	159	158
Observations	589	585	570	555	551	537

Notes: *,**,*** denote 10%, 5%, and 1% levels of significance, respectively. Robust standard errors, in parentheses, are clustered at the country level. All trade and income variables are five-year non-overlapping averages. All models include the log of population; the institutional quality of the country; and year and region fixed effects. The gravity equation for immigration is extended by the cultural proximity variables of Bahar and Rapoport (2018). The first-stage F-stats for excluded instruments are ≥ 27.81.

6.2 Out-of-sample predictions and exclusion restrictions

In the worst case scenario, the baseline estimates may be inconsistent because of feedback effects from income to the regressors; for example, poor countries specializes in primary production and rich countries have a disproportionately large trade in high-tech products. Thus, most bilateral trade data for high-tech products between countries i and j will be missing or zero for poor countries. If the instruments are created from observed bilateral relationships only, as is mostly done in the literature, see Deij (2018), then the exclusion restriction will be violated if there is a systematic relationship between income and number of observed bilateral trade flows with non-zero values. To address this issue, we follow the recommendation of Deij (2018) by including all possible ij combinations in Eq. (3); even if the trade between two countries is zero or unrecorded. The results, which are shown in Online Appendix Table A15, are almost identical to the baseline regression results. From this we can infer that the exclusion restriction is not violated due to a systematic relationship between income and observed non-zero bilateral trade across countries and goods.

6.3 Estimates in differences

To check whether the baseline results are driven by unobserved cross-country heterogeneity or trends that the dependent and independent variables have in common, we estimate the relationship between trade and income using non-overlapping 5-year first differences. First-difference estimates may also reduce potential multicollinearity, depending on the effects of the first-difference transformation on the disturbance term.

The results are presented in Table A7. Except for the absolute magnitudes of the coefficients, the results are largely consistent with the 2SLS baseline level-regressions: High-tech trade and low-tech net exports have significantly positive income effect, while the income effects of exports of primary products are negative. The statistical significance of the coefficients of trade in primary products is low, partly reflecting a large noise-to-signal ratio. The downside of first-difference estimates is that 1) they generally have a larger attenuation bias than level estimates; 2) they only capture short-run effects; and 3) the within country identifying variation in the data is modest. Despite this, the first-difference regression results suggest that the baseline results are not driven by unobserved cross-country heterogeneity.

6.4 North-South trade

Since poor countries tend to specialize in production of unsophisticated goods more than rich countries, the baseline results may be driven by the per capita income of the country. To address this issue, we split the sample into two groups of countries by their level of average per capita income over the 1962-2019 period. The top 25% of the countries form the 'North' and the bottom 75% form the 'South'. These estimates reveal the extent to which the income effect of trade depends on the identity of the trading partner and, therefore, whether the exclusion restriction is violated in the baseline regressions due to this factor.

In the 2SLS estimates in Table 11, the country sample is restricted to the South and two sets of trading partners, viz the South (Columns (1)-(3)), South-South, and the whole world (Columns (4)-(6)), South-All. North-North and North-All estimates are presented in the Online Appendix

Table 11: The effect of trade on income, by income levels of the trading partners

	(1)	(2)	(3)	(4)	(5)	(6)
	Ln(Real GDP per capita)					
	South - South			**South - All**		
	Total Trade	Imports	Exports	Total Trade	Imports	Exports
	Panel A: All products					
Ln T^{TT}	-0.096	-0.464***	0.173**	0.368**	-0.211	0.400***
	(0.112)	(0.150)	(0.074)	(0.154)	(0.197)	(0.103)
Mean of DV	7.69	7.70	7.69	7.69	7.69	7.69
# of countries	124	124	124	124	124	124
Observations	1,020	1,011	1,011	1,020	1,010	1,011
	Panel B: By product categories					
Ln T^{PP}	-0.165	0.112	-0.232***	-0.583***	0.123	-0.295***
	(0.131)	(0.136)	(0.052)	(0.134)	(0.182)	(0.059)
Ln T^{MQ}	0.289***	0.119**	0.115***	0.206***	0.056	0.075**
	(0.059)	(0.058)	(0.032)	(0.063)	(0.078)	(0.029)
Ln T^{LT}	-0.714***	-1.166***	-0.040	-0.478**	-1.723***	-0.057
	(0.204)	(0.171)	(0.114)	(0.192)	(0.230)	(0.074)
Ln T^{HT}	0.175	0.395***	0.121	0.600***	1.134***	0.198***
	(0.169)	(0.131)	(0.081)	(0.183)	(0.220)	(0.060)
Mean of DV	7.70	7.70	7.72	7.69	7.69	7.70
# of countries	124	124	123	124	124	124
Observations	1,013	1,007	956	1,018	1,008	982

Notes: *,**,*** denote 10%, 5%, and 1% levels of significance, respectively.
Robust standard errors, in parentheses, clustered at the country-pair level. All variables are five-year non-overlapping averages. All specifications additionally control for population and institutional quality as well as year and region fixed effects. The first-stage *F*-stats for all excluded instruments are ≥ 52.11.

Table A9). In the South-South regressions the absolute values of the coefficients of low-tech manufacturing and high-tech products, in particular, are substantially below those of the baseline regressions. However, this is not the case with coefficients in the South-All sample for which the coefficients are close to those of the baseline regressions.

From these results it may be tempting to conclude that the South is better off trading with the North than the South. However, such a conclusion is too hasty because these results may have been driven by a violation of the exclusion restriction in the South-South 2SLS regression and an aggregation bias in the OLS regressions. The problem associated with the South-South setup is that the generated instrument/data in the 2SLS/regressions are disproportionately lower for high-tech trade than other traded products in the South-All estimates. In other words, focusing on South-South trade, of which high-tech products form a small share, is likely to induce a severe selection bias, violating the uncorrelated error term assumption for unbiased OLS estimation and the exclusion restriction in the 2SLS specification. Therefore, we cannot say anything about the gains or losses in income from trading with high-income vis-à-vis low-income trading partners by comparing the estimates across the South-South and South-All specifications. What we can conclude from the estimates, however, is that it is not the identity of the country that matters for income but what is traded.

6.5 Alternative goods classification

Decomposing low-tech trade into non-food low-tech manufacturing, and natural resource manufacturing (food processing) and high-tech into medium high-tech and advanced high-tech do not change the principal results. The coefficients of advanced high-tech products are significantly positive for both imports and exports, while that of medium high-tech products are insignificant for imports and significantly positive for exports (Appendix Table A2). The insignificance of imports of medium high-tech products is intuitive because it suggests low knowledge externalities in products with semi-low R&D intensity. For non-food low-tech manufacturing, and natural resource manufacturing (food processing), the coefficients are both significantly negative for overall trade.

7 Trade effects on fertility and education

Thus far, we have argued that the income effects of trade in different product categories may have long-term income effects through fertility and human capital formation. If the reasoning is correct, our main findings should be mirrored in fertility and gross enrollment rate (GER) regressions. To the extent that trade affects income through the QQ-tradeoff following the Galor and Mountford (2008) hypothesis, fertility and education regressions are some of the most powerful robustness checks of the baseline results as income, education and fertility have different stochastic properties and are determined by different factors.

To investigate the effects of trade across product categories on fertility and education, we estimate the following two models:

$$\begin{aligned} GER_{it} &= \kappa_0^e + \kappa_1^e \ln T_{it}^{HT} + \kappa_2^e \ln T_{it}^{LT} + \kappa_3^e \ln T_{it}^{MQ} + \kappa_4^e \ln T_{it}^{PP} \\ &+ \kappa_5^e \ln \text{Pop}_{it} + \kappa_6^e \ln Inst_{it} + \kappa_7^e \ln Comp_{it} + \kappa_r^e + \kappa_t^e + \epsilon_{it}^f, \end{aligned} \tag{10}$$

$$\begin{aligned} \ln TFR_{it} &= \kappa_0^f + \kappa_1^f \ln T_{it}^{HT} + \kappa_2^f \ln T_{it}^{LT} + \kappa_3^f \ln T_{it}^{MQ} + \kappa_4^f \ln T_{it}^{PP} \\ &+ \kappa_5^f \ln Pop_{it} + \kappa_6^f \ln Inst_{it} + \kappa_7^f \ln CMR_{it} + \kappa_r^f + \kappa_t^f + \epsilon_{it}^f, \end{aligned} \tag{11}$$

where GER is gross enrollment rates; $Comp$ is the number of compulsory school years; CMR is the crude mortality rate (deaths per 1000 population); and TFR is the total fertility rate, measured as the average number of children born to a woman over her lifetime conditional on the contemporaneous age-specific fertility rates throughout her lifetime. Here, GER is estimated as the weighted average of primary (7/17), secondary (5/17), and tertiary (5/17) gross enrollment rates, with figures in parentheses denoting relative weights that signify years of education at each level. GERs are measured as the fraction of the population of schooling age that is enrolled in primary, secondary or tertiary education. For brevity, we only show the the second-stage IV-regressions since the relevance criteria are satisfied by a large margin, where the lowest F-test for exclusion restrictions is presented in the notes to the tables.

Although the fertility and educational decisions are made simultaneously in the QQ-model, we have kept trade unlagged as in the other models for expositional simplicity and because the educational decision is also contemporaneously affected by trade. For example, if the returns to education (including the costs of education) have changed between the time of the child's birth and the time at which the child enters education, then, if possible, the parents will revise the number of additional children they previously planned. Furthermore, the access to credit to fund education may have changed between the time of birth and the time of education (Galor and Weil, 1996). Estimates with lagged trade variables, which are presented in the Online Appendix Table A10, give results that are almost identical to the estimates without lagged trade.

7.1 Education

The results of estimating Eq. (10) (gross enrollment rate) are presented in Table 12. The coefficients of overall trade openness are insignificant because of counterbalancing effects from imports (negative) and exports (positive). In the estimates with trade decomposed, the coefficients are significantly positive for high-tech imports and exports, significantly negative for exports of primary products, and significantly positive for net exports of low-tech manufacturing products.

Remarkably, the coefficient of mining exports is significantly positive for mining, suggesting that mining may not be as detrimental for economic development as is often expressed in the natural resource curse literature. This result is consistent with Gollin et al. (2016) who finds a significant

Table 12: The effect of trade on gross enrollment rate (1962-2019)

	(1)	(2)	(3)	(4)	(5)	(6)
	Weighted Gross Enrollment Rate					
	Total Trade		Imports		Exports	
Ln T^{TT}	0.534		-1.078		1.047**	
	(0.750)		(0.786)		(0.516)	
Ln T^{PP}		-1.788***		0.389		-0.881***
		(0.548)		(0.653)		(0.261)
Ln T^{MQ}		1.042***		0.287		0.469***
		(0.312)		(0.360)		(0.145)
Ln T^{LT}		-1.112		-5.585***		0.074
		(0.933)		(1.284)		(0.488)
Ln T^{HT}		1.511**		3.601***		0.690***
		(0.713)		(1.076)		(0.260)
Ln(Population)	-0.024	-0.512**	-0.308	-0.960***	-0.026	-0.277
	(0.194)	(0.216)	(0.240)	(0.299)	(0.171)	(0.178)
Institutional Quality	3.277***	3.730***	3.470***	2.860***	3.218***	3.223***
	(1.003)	(0.848)	(0.982)	(0.932)	(0.971)	(0.865)
Ln(Compulsory School Years)	2.256**	1.365	2.423**	2.089**	1.819*	0.810
	(1.125)	(0.962)	(1.150)	(1.017)	(1.069)	(0.988)
Mean of DV	24.41	24.41	24.44	24.44	24.44	24.52
# of countries	143	143	143	143	142	141
Observations	740	739	737	736	736	729

Notes: *,**,*** denote 10%, 5%, and 1% levels of significance, respectively. Robust standard errors, in parentheses, are clustered at the country level. All trade and income variables are measured in five-year non-overlapping averages. All specifications control for year and region fixed effects. The first-stage F-stats for excluded instruments are ≥ 133.12.

causal positive effect running from mineral and fuel resource exports to urbanization. This is because a large fraction of the export earnings are spent on urban non-tradables, which in turn draw rural labor into the urban centers. The mineral-induced urbanization increases education because access to education is substantially easier in urban centers than in the rural areas. Gollin et al. (2016), for example, find that urban enrollment rates are independent of mineral exports, implying that an expansion of mineral exports increases the level of education at the country level.

7.2 Fertility

The results of estimating the fertility model, Eq. (11), are presented in the top panel in Table 13. The Sanderson-Windmeijer tests suggest that the instrument relevance criteria is satisfied in all cases. The coefficients of overall trade openness are significantly negative, suggesting a positive income effect of trade on income through fertility. Like education, this positive income effect will not be captured in the income regressions because of the delayed income effects through education. This delay will be furthered by the generations it takes for the age profile of the population to reach a new steady state after a fertility transition, because the pre-transition share of the population of fertile age is slow to converge to its steady state.

Like the income and education estimates, we find differentiated fertility-effects of decomposed trade: The coefficient of exports of primary products is significantly positive, the coefficients of exports and imports of high-tech manufacturing goods are both significantly negative, and the coefficients of low-tech manufacturing exports (imports) are negative (positive). These results are largely mirror-images of the income and the enrollment regressions and suggest that 1) the QQ-tradeoff is a potentially important channel though which trade transmits to income; and 2) that the differential trade-effects found in the baseline income regressions are not significantly driven by violations of the exclusion restrictions.

Remarkably, the coefficient of mining exports is significantly positive, deviating from the mirror image scenario in which the coefficient should have a sign opposite to that of the income and gross enrollment estimates. This ostensible contradiction, however, is intuitive and consistent with the QQ-framework. The income increase in the oil-rich countries is not fueled by a fertility transition as a result of increasing returns to education, but by the direct income effects of the mining revenue. This result gains support from the findings of Gollin et al. (2016) in which the returns to education are negatively related to mineral exports.

The results that exports of low-tech manufacturing goods put downward pressure on fertility is consistent with the fertility model of Galor and Mountford (2008), because females have a comparative advantage in employment opportunities in low-tech manufacturing. As shown by Do et al. (2016) and Madsen et al. (2020), the fertility decision, in addition to the returns to human capital, depends on the relative opportunities of females vis-à-vis males, as reflected in the gender wage gap. From the onset of the Industrial Revolution as well as today, females always domi-

Table 13: The effect of trade on total fertility rate (1962-2019)

	(1)	(2)	(3)	(4)	(5)	(6)
	Ln(Total Fertility Rate)					
	Total Trade		Imports		Exports	
	Panel A: All countries					
Ln T^{TT}	-0.097***		-0.089***		-0.061***	
	(0.018)		(0.021)		(0.013)	
Ln T^{PP}		0.169***		0.005		0.080***
		(0.015)		(0.021)		(0.007)
Ln T^{MQ}		0.011		-0.047***		0.013***
		(0.008)		(0.011)		(0.004)
Ln T^{LT}		-0.075***		0.072**		-0.029**
		(0.027)		(0.036)		(0.011)
Ln T^{HT}		-0.167***		-0.094***		-0.091***
		(0.025)		(0.030)		(0.008)
Ln(Population)	-0.014***	-0.007	-0.015**	0.010	-0.003	0.011**
	(0.005)	(0.006)	(0.006)	(0.008)	(0.005)	(0.005)
Institutional Quality	-0.343***	-0.287***	-0.351***	-0.321***	-0.342***	-0.178***
	(0.029)	(0.029)	(0.029)	(0.029)	(0.029)	(0.030)
Crude Death Rate	0.011***	0.009***	0.010***	0.008***	0.012***	0.003
	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)
Mean of DV	1.13	1.13	1.12	1.12	1.12	1.11
# of countries	164	164	164	164	164	164
Observations	1,447	1,445	1,437	1,435	1,434	1,403
	Panel B: Poor countries					
Ln T^{TT}	-0.131***		-0.100***		-0.085***	
	(0.023)		(0.028)		(0.014)	
Ln T^{PP}		0.148***		-0.024		0.079***
		(0.020)		(0.026)		(0.010)
Ln T^{MQ}		-0.003		-0.054***		0.011***
		(0.009)		(0.012)		(0.004)
Ln T^{LT}		-0.104***		0.163***		-0.044***
		(0.032)		(0.039)		(0.013)
Ln T^{HT}		-0.158***		-0.147***		-0.084***
		(0.032)		(0.038)		(0.010)
Ln(Population)	-0.019***	-0.015*	-0.019**	0.022**	-0.005	0.004
	(0.006)	(0.008)	(0.008)	(0.010)	(0.005)	(0.006)
Institutional Quality	-0.193***	-0.189***	-0.201***	-0.156***	-0.197***	-0.111***
	(0.034)	(0.034)	(0.034)	(0.035)	(0.034)	(0.036)
Crude Death Rate	0.009***	0.006**	0.008***	0.004	0.010***	0.004
	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)
Mean of DV	1.30	1.30	1.30	1.30	1.30	1.29
# of countries	124	124	124	124	124	124
Observations	1,033	1,031	1,023	1,021	1,024	994

Notes: *,**,*** denote 10%, 5%, and 1% levels of significance, respectively. Robust standard errors, in parentheses, are clustered at the country level. All trade and income variables are measured in five-year non-overlapping averages. All specifications control for year and region fixed effects. The first-stage F-stats for all excluded instruments are ≥ 289.27.

nated employment in the textile and the food processing industries - industries that dominate low-tech manufacturing (Galor, 2022). Similarly, Do et al. (2016) show theoretically and empirically that countries with a comparative advantage in female-labor-intensive goods have a comparatively lower fertility rate because the opportunity costs of children are higher in those countries. This reasoning gains support from the baseline income regressions in which per capita income is negatively affected by imports of these goods because they crowd out the job opportunities of females.

While the fertility-effects of low-tech manufacturing in the estimates in the top panel in Table 13 are consistent with the model of Galor and Mountford (2008), the absolute values of the parameters are likely to be watered down by countries that have completed the fertility transition. To cater for this, we exclude the rich countries from the sample in the estimates in the lower panel in Table 13. While the principal results for the poor country sample are the same as those of the baseline regressions in the top panel, one result sticks out: The absolute values of the coefficients of low-tech trade are substantially larger than those of the full-sample estimates. The specialization effects (exports-imports) are three times as large as those of the baseline regression, suggesting that the positive income effects of specialization in low-tech production through the fertility channel is substantial for developing countries.

Next, consider the controls. As predicted by standard models, the coefficients of crude death rates are significantly positive because parents target a certain number of children that survive to adulthood. Good institutions have significantly positive effects on education and significantly negative effects on fertility, essentially because they provide inexpensive educational opportunities for the school age population. For population, almost all the coefficients are significantly negative in the enrollment as well as fertility estimates (Tables 12 and 13). The negative impact of population on education is through the negative income effects of the population growth drag, which in turn reduces fertility and investment in human capital.

7.3 Robustness checks of the fertility and enrollment models

First, to check for robustness of the fertility and gross enrollment models to potentially important confounders, we include immigration and FDI in the enrollment and fertility regressions, see Online Appendix Table A12. The parameter estimates of trade are almost identical to those of the baseline gross enrollment and fertility regressions, giving further support to the Galor and Mountford (2008) model in which trade drives the QQ-tradeoff through the incentive structure.

The coefficients of FDI are insignificant in all cases, while the coefficient of immigration is only significantly positive at the 10% level in one case in the models in which imports and exports are decomposed into technology groups. From these results we can conclude that the coefficients of trade in the fertility and gross enrollment models have not been influenced by FDI or immigration effects. Furthermore, these results suggest that immigration does not transmit to income through the QQ-tradeoff channel, which is intuitive since the incentive structure is not affected by immigration provided that the skills of the immigrants do not significantly differ from those of the labor force of the host country.

Finally, as a check on the validity of the exclusion restrictions in the fertility and enrollment regressions, we undertake out-of-sample estimates (see, for results, Online Appendix Table A13). The results are almost identical to those of the baseline regression, suggesting that the exclusion restriction is not violated due to a systematic relationship between fertility or education and the observed non-zero bilateral trade across countries and goods.

7.4 Is trade transmitted to income through fertility and education?

Next, we conduct a mediation analysis to verify the role of fertility and gross enrollment as pathways through which trade effects income. Furthermore, we quantify the relative importance of these two transmission channels. Mathematically,

$$\frac{\mathrm{dGDP\ pc}}{\mathrm{dTrade}} = \frac{\partial \mathrm{GDP\ pc}}{\partial \mathrm{Trade}} + \frac{\partial \mathrm{GDP\ pc}}{\partial \mathrm{Fertility}}\frac{\partial \mathrm{Fertility}}{\partial \mathrm{Trade}} + \frac{\partial \mathrm{GDP\ pc}}{\partial \mathrm{Education}}\frac{\partial \mathrm{Education}}{\partial \mathrm{Trade}}, \tag{12}$$

where the first right-hand-side term represents the direct effect of trade on income, while the other two terms represent the income effects that are mediated by fertility and education. We estimate the indirect effects as the product of the direct effect of trade on fertility (education) and the direct effect of fertility (education) on income (Sobel, 1982). Following Preacher and Hayes (2004), we calculate bootstrapped standard errors for the indirect effect. Table A18 presents the relationship between the independent variables, the mediator, and the dependent variable relating to Equation (12). The coefficients all represent direct effects.

The estimated direct effects of trade in the four product categories presented in A19 are consistent with our main results. This suggests that our mediation model in Equation (12) does a good job of mimicking the causal channels we establish in the sections before. All estimates of the direct and the indirect effects are presented together in Table A19.

A one percentage point increase in total trade of primary products decreases GDP by $0.93\%(0.496+0.186+0.248)$, of which $0.47\%((0.186+0.248)/0.93)$ is through an increase in fertility or a decrease in gross enrollments. For exports and imports of primary products, the two mechanism variables explain 100% and 31% of the total effect. The indirect effects of trade in mining and low-tech products via education and fertility are mixed, in terms of their signs and statistical significance, and small relative to the direct effects. It is important to note here that trade in low-tech product specialization increases income by reducing fertility but reduces income by discouraging enrollment. This is in line with the discussion above: Low-tech production, which often increases female employment and wages, may decrease fertility and increase per capita income.

The role of these mediating variables is also extremely important when examining the effect of high-tech trade. For example, the around $49\%((0.237+0.407)/(0.680+0.237+0.407))$ of the total income effect of trade in high-tech products on income is via fertility and education. The contributions of fertility and education are about the same for imports (49%) as well as exports (56%) of high-tech products, suggesting that a large share of the total income effects are mediated through fertility and education. The mediating effects of fertility and education are likely to increase over time since they take several decades before the full income effects are fully borne out.

8 Quantitative effects of trade on income, education and fertility

Thus far, we have concentrated on the qualitative effects on trade. In the section, we focus on the economic effects of trade on per capita income, education and fertility. Table 14 summarizes the key baseline IV parameter estimates (top panel) and the associated semi-elasticities (bottom panel). The full elasticities can be read from the replications of the baseline estimates in the top panel; however, semi-elasticities are emphasized here because they are independent of the level of trade openness for each trade category.

The table gives two striking insights. First, taking the average of the semi-elasticities for total trade openness of product categories weighted by their trade share gives a negative income effect of trade, which explains the low positive income effects of trade found in the trade literature. Frankel and Romer (1999), for example, finds that a 10-percentage point increase in trade openness is associated with an income increase of 8.2% (OLS) and 29.6% (IV) based on the country sample of Mankiw et al. (1992), suggesting a relatively modest income effect of trade. Second, the absolute values of the semi-elasticities are high for trade in high-tech, low-tech and primary products, suggesting that trade can be a blessing or a curse depending on the composition of the trade.

Next, consider two counterfactual experiments, where the first is relevant mostly for poor countries and the other relevant for rich countries. Based on the semi-elasticities, a simultaneous one-percentage point reduction in imports of low-tech manufactured products and exports of primary products so that the trade balance remains unaffected, results in a 35% increase in income. This change can be achieved by a switch from specialization in primary production to low-tech manufacturing production, often achieved through employment-induced migration from the rural to the urban sector. For education, this switch increases enrollments by 111% (39 + 71). To find the long-run income-effects of education, we use the steady state conditions of the Solow model. In steady state, there is a one-to-one relationship between enrollments rates and per capita income when the income share of capital is set to 0.30 and the income share of human capital is set to 0.35 (see, for derivations, Mankiw et al., 1992). Thus, the 111% increase in GERs yields an income-effect of 111%. This income effect is approximately three times that of the direct income effects (see the estimates in the first four columns in Table 14). The long-term effects on income meditated by education are not fully captured by the income regressions because of the long delayed income response of education. The full economic effects of an increase in enrollment rates of the cohort of children at the age of six, for example, will first be borne out after approximately six decades when this age cohort eventually retires.

For fertility, a trade balance neutral one-percentage point reduction in exports of primary products matched by a reduction in imports of low-tech manufacturing products, reduces fertility by 4.5%. The income effects of this fertility change cannot easily be assessed as we need to know the preference parameters and the size of the population growth drag to find the mapping between fertility and income. Despite this, the absolute value of semi-elasticities for fertility appear comparatively low, partly because the absolute values of the semi-elasticities are pulled down by the rich countries, as discussed in Section 6.4. Another reason for the ostensibly low fertility effect vis-à-vis enrollment rates, is statistical: A 100% increase in GERs starting at 10% for a low-income country, corresponds to a 10 percentage point increase in GERs, while a 10% reduction in the fertility rate of six live births, translates into a 10 percentage point decrease in the scale from zero to six, assuming that the maximum total fertility rate is six. Overall, this counterfactual shows that well-designed industry and trade policies can have marked income consequences for developing countries with an abundance of low-skilled females working in the agricultural sector.

Table 14: The effect of trade on income, education, and fertility

	Ln(Real GDP per capita)				**Weighted GER**				**Ln(TFR)**			
Category $k =$	PP	MQ	LT	HT	PP	MQ	LT	HT	PP	MQ	LT	HT
	Second Stage Coefficient											
Ln T^k	-0.691***	0.165***	-0.868***	0.924***	-1.788***	1.042***	-1.112	1.511**	0.169***	0.011	-0.075***	-0.167***
	(0.122)	(0.062)	(0.191)	(0.160)	(0.548)	(0.312)	(0.933)	(0.713)	(0.015)	(0.008)	(0.027)	(0.025)
Ln IM^k	-0.017	0.022	-1.539***	0.984***	0.389	0.287	-5.585***	3.601***	0.005	-0.047***	0.072**	-0.094***
	(0.166)	(0.095)	(0.259)	(0.311)	(0.653)	(0.360)	(1.284)	(1.076)	(0.021)	(0.011)	(0.036)	(0.030)
Ln EX^k	-0.332***	0.094***	-0.237***	0.296***	-0.881***	0.469***	0.074	0.690***	0.080***	0.013***	-0.029**	-0.091***
	(0.054)	(0.030)	(0.081)	(0.059)	(0.261)	(0.145)	(0.488)	(0.260)	(0.007)	(0.004)	(0.011)	(0.008)
	Semi-elasticities											
T^k	-17.275	4.108	-6.582	8.062	-45.142	25.940	NA	13.183	4.267	NA	-0.569	-1.457
IM^k	NA	NA	-19.673	12.269	NA	NA	-71.393	44.899	NA	-3.339	0.920	-1.172
EX^k	-15.091	3.602	-4.419	8.601	-39.163	17.973	NA	20.051	3.556	0.498	-0.541	-2.644

As the other counterfactual, consider a trade-balance preserving one-percentage point increase in high-tech imports plus exports. This results in a contemporary income increase of 21%, which is amplified over time by the persistent growth effects as shown in Section 5. In contrast to low-tech and primary production, the gain from a high-tech strategy does not derive from specialization in high-tech net exports because of the externalities associated with high-tech imports, as discussed above. For education and fertility, the high-tech trade-expansion results in a 65% increase in enrollment rates and a 3.8% reduction in the fertility rate.

9 Discussion and concluding remarks

Classifying traded goods into various categories according to their degree of sophistication, we find that imports and exports of high-tech manufactured goods have significantly positive effects on income and education and negative effects on fertility, while the reverse results are found for exports of primary products. Furthermore, consistently with the predictions of the learning-by-doing model and second-generation Schumpeterian endogenous growth theory, we show that trade in high-tech products has permanent growth effects.

In apparent contradiction to the predictions of the learning-by-doing model, we, furthermore, find a robust positive income effect of specialization in low-tech manufacturing such as textile production and food processing, particularly for developing countries that have not completed their fertility transition. This result does not imply that specialization in low-tech production directly promotes learning-by-doing because it is an insufficient channel through which the economy is brought into a persistent growth trajectory. Instead, female-intensive low-tech manufacturing changes the QQ-tradeoff in favor of lower fertility and more education as low-skilled female labor is drawn into the urban labor force, as predicted by the model of Galor and Mountford (2008). This route of development was taken by the South-East Asian miracle economies in the 1960s when they expanded low-tech manufacturing production of textiles and standardized consumer goods. Since then, these economies have moved up the technology ladder to become medium to large-scale producers of high-tech products.

Several robustness tests are carried out to check for the validity of our identification strategy based on Frankel and Romer (1999) and extended by Feyrer (2019). The robustness checks give no evidence of a violation of the exclusion restrictions. First, the results are robust to the inclusion of out-of-sample bilateral trade predictions that are used to form the instrument, which is shown by Deij et al. (2021) to be an important check for exclusion restrictions when the instruments are generated from the gravity model. Second, we show that migration and trade are determined by different geographic characteristics, suggesting that the exclusion restriction is not violated because the geographic instruments capture the income effects of immigration. Third, and most importantly, the fertility and the education regression results are consistent with those of the income regressions, and yet, fertility, education, and income are largely determined by different factors. Finally, North-South trade regressions show that the baseline results are not determined by the identity of the country, but rather by the product composition of imports and exports.

Our findings have significant implications for cross-country income inequality and economic development. First, since trade in high-tech products is concentrated in the advanced countries, the globalization of trade since the 1960s has benefited growth in the rich countries more than countries below the technology frontier. This has resulted in an increasing income gap between rich and poor because of the persistent income effects derived from high-tech trade. Thus, the expansion of trade in high-tech products is a trade-off between cross-country inequality and income growth at the world level.

Second, large economic dividends derive from low-tech female-intensive manufacturing production in countries that have not completed or initiated their fertility transition; typically, countries with a large rural low-skilled female labor force. Third, the influence of trade on per capita income and income growth cannot be considered in isolation from the QQ-tradeoff mechanism: Not only because education and fertility are key channels through which trade transmits to income, but also because the QQ-tradeoff is strongly complementary to the learning-by-doing model in understanding the economic effects of trade.

This brings us back to the fundamental question: "Does trade cause (labor) productivity?" For overall trade, it depends. For countries trading in high-tech products the answer is unambiguously affirmative regardless of whether it is imports or exports. For trade in low-tech products, the answer is ambiguous. Countries that have not completed their fertility transition gain from trade in low-tech manufacturing if they specialize in low-tech production. While trade in high-tech benefit all involved trading partners, specialization in low-tech is beggar-thy-neighbor at the global level unless the expansion in low-tech production in developing countries is at the expense of countries that have completed the fertility transition. For primary production, trade unambiguously drags income down at the world and country levels.

The second fundamental question, which has, to our knowledge, not been addressed in the empirical trade literature is: "Does trade cause *growth*?". The answer is 'yes' because middle- and high-income countries that engage in high-tech trade gain in terms of per capita growth. Low-income and even middle-income countries engaging in trade in primary products, minerals and oil will experience a delayed fertility transition because of the incentive structure created from trade in these products through the QQ-tradeoff mechanism. Thus, while the growth impact of trade at the global level is likely positive due to the strong growth externalities from high-tech trade, the gap between rich and poor countries is likely to increase over time as a consequence.

Data availability: The data that support the findings of this study are available from the corresponding author upon request.

Code availability: The code that supports the findings of this study is available from the corresponding author upon request.

Declarations:

Funding and/or competing interests: Jakob B. Madsen acknowledges financial support from the Australian Research Council (DP170100339; DP220102557). The authors have no competing interests to declare that are relevant to the content of this article.

Author contributions: All authors contributed equally to the study.

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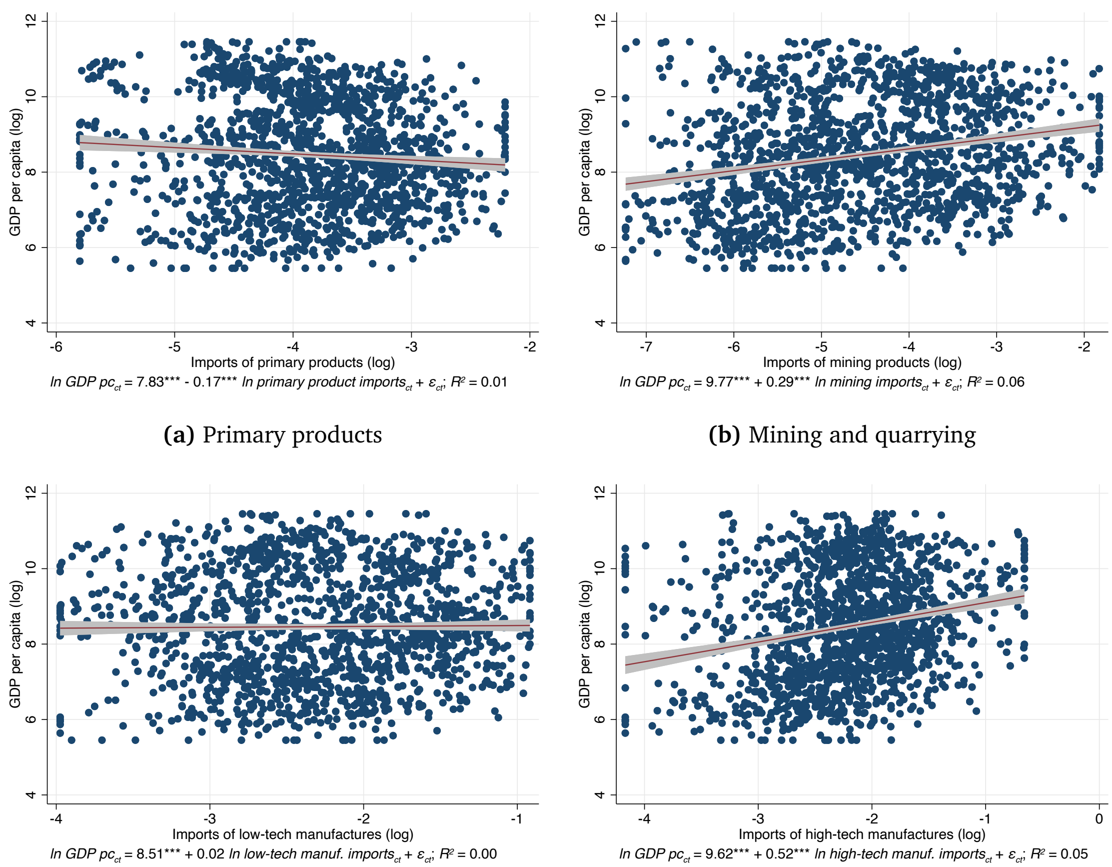
A1 Appendix

A1.1 Association between exports/imports and income

Figure A1: Imports in different product categories and GDP per capita



(a) Primary products

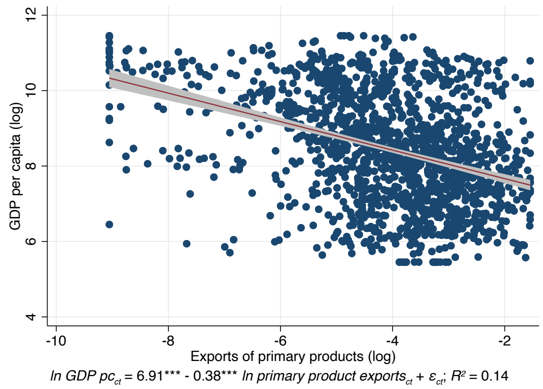
(b) Mining and quarrying

(c) Low- to medium-technology manufactures

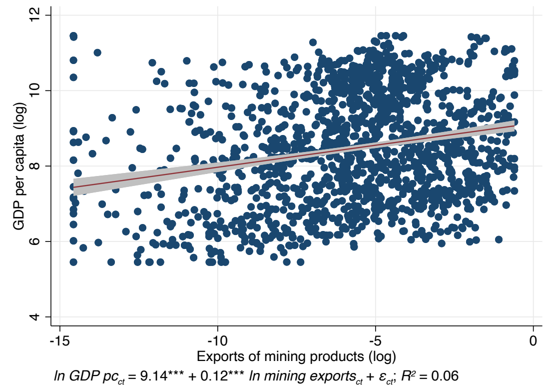
(d) High-technology manufactures

Sources: Bilateral SITC 3-digit level annual trade data from UN-COMTRADE database and GDP per capita, (constant 2010 USD) from World Bank (2020) for years 1962-2019.

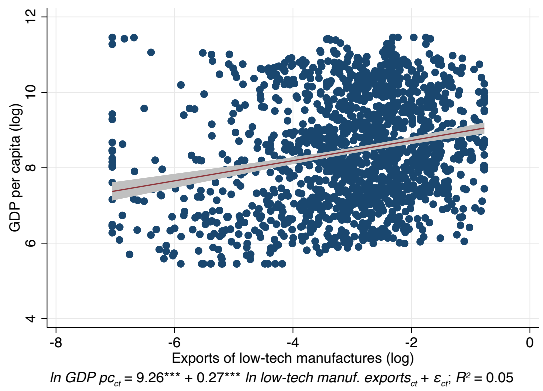
Figure A2: Exports in different product categories and GDP per capita



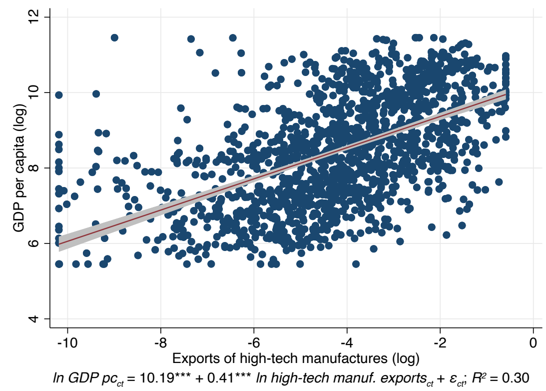
(a) Primary products



(b) Mining and quarrying



(c) Low- to medium-technology manufactures



(d) High-technology manufactures

Sources:Bilateral SITC 3-digit level annual trade data from UN-COMTRADE database and GDP per capita, (constant 2010 USD) from World Bank (2020) for years 1962-2019.

A1.2 Further robustness tables

Table A1: Categorization of traded products based on the sophistication of the production process

Category	Examples	SITC code
Primary Products	Fresh fruit, meat, rice, cocoa, cereals, tea, coffee, timber, live animals for food	001, 011, 022, 025, 034, 036, 041, 042, 043, 044, 045, 054, 057, 071, 072, 074, 075, 081, 091, 121, 211, 212, 222, 223, 232, 244, 245, 246, 261, 263, 268 ,291, 292
Mining products	Coal, crude petroleum, gas, Iron ore , precious metal, uranium	271, 273, 274, 277, 278, 322, 333, 341, 681, 682, 683, 684, 685, 686, 687
Low-technology manufactures	Prepared fruits or meat, beverages, wood products, tobacco, materials of rubber, vegetable oils, base metals (except steal), cement, gems, cheese and curd, vegetables, preserved and prepared, textile fabrics, clothing, footwear, leather manufactures, travel goods, handbags	012, 014, 023, 024, 035, 037, 046, 047, 048, 056, 058, 061, 062, 073, 098, 111, 112, 122, 233, 247, 248, 251, 264, 265, 269, 281, 282, 286, 287, 288, 289, 323, 334, 335, 411, 423, 424, 431, 511, 514, 515, 516, 522, 523, 531, 532, 551, 592,611, 612, 613, 621, 625, 628, 633, 634, 635,641,642, 651, 652, 654, 655, 656, 657, 658, 659,661, 662, 663, 664, 667, 688, 689, 665, 666, 673, 674, 675, 676, 677, 679, 691, 692, 693, 694, 695, 696, 697, 699, 821, 831, 842, 843, 844, 845, 846, 847, 848, 851, 893,894, 895, 897, 898, 899
High-technology manufactures	Passenger motor vehicle excluding buses, lorries, special motor vehicles N.E.S, manufactured fertilizers, railway vehicles, textile and leather machinery, television receivers, transistors, power generating equipment, pharmaceuticals, aircraft, optical instruments, steam engines, turbines,electric machinery	266, 267, 512, 513, 524, 533,541, 553, 554, 562, 572, 582, 583, 584, 585, 591, 598, 653, 671, 672, 678, 711, 712, 713, 714,716, 718, 721, 722, 723, 724, 725, 726, 727, 728, 736, 737, 741, 742, 743, 744, 745, 749, 751, 752, 759, 761, 762, 763, 764, 771, 772, 773, 774, 775, 776, 778, 781, 782, 783, 784, 785, 786, 791, 792, 793, 812, 871, 872, 873, 882, 884, 885, 874, 881, 951
Miscellaneous manufactures, N.E.S	Electricity, cinematographic film, printed matter, special transactions, works of art	351, 883, 892, 896, 911, 931, 941, 961, 971

Notes: We follow Lall (2000) in our classification, further distinguishing between mining and primary products and combining natural resource based manufacturing and low-tech manufacturing into one category as “Low-tech manufacturing” and Medium-tech manufacturing and High-tech manufacturing as “High-technology Manufacturing” in accordance with the study’s objectives. The data from 1962-1975 and 1976-2019 are based on SITC revision 1 (converted into revision 2) and revision 2, respectively.

Table A2: Robustness to breaking the four product categories down further by sophistication of production processes

	(1)	(2)	(3)	(4)	(5)	(6)
	Ln(Real GDP per capita)					
	Five categories			**Seven Categories**		
	Total Trade	Imports	Exports	Total Trade	Imports	Exports
	Panel A: All products					
Ln T^{TT}	0.098	-0.415*	0.304***	0.099	-0.418*	0.305***
	(0.175)	(0.230)	(0.110)	(0.174)	(0.230)	(0.109)
Mean of DV	8.38	8.38	8.38	8.38	8.38	8.38
# of countries	162	162	162	162	162	162
Observations	1,388	1,378	1,377	1,388	1,378	1,377
	Panel B: By product categories					
Ln T^{PP}	-0.691***	0.033	-0.339***	-0.626***	0.089	-0.326***
	(0.122)	(0.168)	(0.057)	(0.118)	(0.177)	(0.059)
Ln T^{MQ}	0.166***	0.016	0.093***	0.175**	0.053	0.078**
	(0.062)	(0.095)	(0.030)	(0.074)	(0.085)	(0.033)
Ln T^{LT}	-0.878***	-1.667***	-0.243***	-0.378**	-0.032	-0.194***
	(0.201)	(0.290)	(0.084)	(0.158)	(0.247)	(0.072)
Ln T^{HT}	0.918***	0.935***	0.293***	0.522***	0.830***	0.166**
	(0.160)	(0.301)	(0.059)	(0.176)	(0.219)	(0.083)
Ln T^{MS}	0.014	0.140	0.011	-0.002	0.099	-0.002
	(0.082)	(0.119)	(0.046)	(0.085)	(0.114)	(0.047)
Ln T^{NRB}				-0.553***	-1.425***	-0.105
				(0.172)	(0.250)	(0.078)
Ln T^{MT}				0.415	-0.265	0.229**
				(0.306)	(0.327)	(0.099)
Mean of DV	8.38	8.38	8.41	8.38	8.38	8.41
# of countries	162	162	162	162	162	162
Observations	1,384	1,375	1,336	1,381	1,375	1,327

Notes: *,**,*** denote 10%, 5%, and 1% levels of significance, respectively. Robust standard errors, in parentheses, are clustered at the country level. All trade and income variables are five-year non-overlapping averages. *NRB* and *MT* denote natural resource-based manufacturing and medium-tech manufacturing, respectively. All specifications additionally control for the country's institutional quality and the log of population as well as year and region fixed effects. The first-stage F-stats for all excluded instruments are ≥ 161.11.

Table A3: Robustness to excluding major oil producers

	(1)	(2)	(3)	(4)	(5)	(6)
	Ln(Real GDP per capita)					
	Baseline sample			**Excluding Major Oil Producers**		
	Total Trade	Imports	Exports	Total Trade	Imports	Exports
	Panel A: All products					
Ln T^{TT}	0.098	-0.415*	0.304***	0.042	-0.234	0.159
	(0.175)	(0.230)	(0.110)	(0.178)	(0.236)	(0.111)
Mean of DV	8.38	8.38	8.38	8.30	8.31	8.31
# of countries	162	162	162	141	141	141
Observations	1,388	1,378	1,377	1,229	1,221	1,221
	Panel B: By product categories					
Ln T^{PP}	-0.691***	-0.017	-0.332***	0.551***	-0.014	-0.276***
	(0.122)	(0.166)	(0.054)	(0.133)	(0.164)	(0.067)
Ln T^{MQ}	0.165***	0.022	0.094***	0.089	0.120	0.057
	(0.062)	(0.095)	(0.030)	(0.082)	(0.106)	(0.036)
Ln T^{LT}	-0.868***	-1.539***	-0.237***	-0.764***	-1.075***	-0.171*
	(0.191)	(0.259)	(0.081)	(0.210)	(0.302)	(0.087)
Ln T^{HT}	0.924***	0.984***	0.296***	0.908***	0.591*	0.292***
	(0.160)	(0.311)	(0.059)	(0.178)	(0.338)	(0.068)
Ln(Population)	-0.285***	-0.321***	-0.168***	-0.222***	-0.252***	-0.131***
	(0.051)	(0.071)	(0.040)	(0.059)	(0.075)	(0.042)
Institutional Quality	1.506***	1.597***	1.337***	1.710***	1.852***	1.579***
	(0.213)	(0.220)	(0.234)	(0.231)	(0.237)	(0.246)
Mean of DV	8.38	8.38	8.40	8.30	8.31	8.33
# of countries	162	162	162	141	141	141
Observations	1,386	1,376	1,348	1,227	1,221	1,195

Notes: *,**,*** denote 10%, 5%, and 1% levels of significance, respectively. Robust standard errors, in parentheses, clustered at the country level. All trade and income variables are five-year non-overlapping averages. All specifications additionally control for population and institutional quality as well as year and region fixed effects. The first-stage F-stats for all excluded instruments are ≥ 165.28.

Table A4: First Stage: The association between reported and predicted trade, by category (1962-2019).

	(1)	(2)	(3)	(4)	(5)	(6)
	log of [...] product trade (T) as % of GDP					
	TT	PP	MQ	LT	HT	MS
Ln $\widehat{T^{TT}}$	0.949***					
	(0.149)					
Ln $\widehat{T^{PP}}$		0.951***				
		(0.202)				
Ln $\widehat{T^{MQ}}$			0.462***			
			(0.148)			
Ln $\widehat{T^{LT}}$				0.879***		
				(0.195)		
Ln $\widehat{T^{HT}}$					1.390***	
					(0.383)	
Ln $\widehat{T^{MS}}$						0.635***
						(0.198)
R^2	0.785	0.771	0.742	0.786	0.688	0.678
Mean of DV	-0.80	-3.06	-3.65	-1.82	-1.99	-4.84
# of countries	160	160	160	160	160	160
Observations	1,386	1,386	1,384	1,385	1,384	1,382
	(7)	(8)	(9)	(10)	(11)	(12)
	log of [...] product imports (M) as % of GDP					
	TT	PP	MQ	LT	HT	MS
Ln $\widehat{M^{TT}}$	0.898***					
	(0.221)					
Ln $\widehat{M^{PP}}$		0.881***				
		(0.320)				
Ln $\widehat{M^{MQ}}$			0.214			
			(0.130)			
Ln $\widehat{M^{LT}}$				0.752***		
				(0.193)		
Ln $\widehat{M^{HT}}$					1.025***	
					(0.213)	
Ln $\widehat{M^{MS}}$						0.391*
						(0.202)
R^2	0.721	0.776	0.791	0.719	0.626	0.743
Mean of DV	-3.92	-4.47	-2.37	-2.25	-5.52	-1.74
# of countries	160	160	160	160	160	160
Observations	1,376	1,374	1,376	1,376	1,373	1,375
	(13)	(14)	(15)	(16)	(17)	(18)
	log of [...] product exports (E) as % of GDP					
	TT	PP	MQ	LT	HT	MS
Ln $\widehat{E^{TT}}$	0.617***					
	(0.227)					
Ln $\widehat{E^{PP}}$		0.530**				
		(0.214)				
Ln $\widehat{E^{MQ}}$			0.388**			
			(0.168)			
Ln $\widehat{E^{LT}}$				0.730**		
				(0.315)		
Ln $\widehat{E^{HT}}$					0.942***	
					(0.320)	
Ln $\widehat{E^{MS}}$						0.649***
						(0.226)
R^2	0.743	0.811	0.803	0.764	0.829	0.688
Mean of DV	-1.74	-4.01	-5.53	-2.93	-4.17	-6.18
# of countries	160	160	160	160	160	160
Observations	1,375	1,374	1,353	1,373	1,361	1,356

Notes: *,**,*** denote 10%, 5%, and 1% levels of significance, respectively. Robust standard errors, in parentheses, are clustered at the country level. All trade and income variables are five-year non-overlapping averages. All specifications additionally control for the country's institutional quality and the log of population as well as year and region fixed effects.

Table A5: Robustness to using alternative fixed effects in the gravity model

VARIABLES	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	Ln(Real GDP per capita)								
	Reporter, Partner, and Year FEs			**Country pair & Year FEs**			**Reporter-year, Partner-year FEs**		
	Total Trade	**Imports**	**Exports**	**Total Trade**	**Imports**	**Exports**	**Total Trade**	**Imports**	**Exports**
	Panel A: All products								
Ln T^{TT}	0.098	-0.415*	0.304***	0.084	-0.413*	0.297***	0.086	-0.206	0.202***
	(0.175)	(0.230)	(0.110)	(0.174)	(0.223)	(0.108)	(0.115)	(0.143)	(0.073)
Mean of DV	8.38	8.38	8.38	8.38	8.39	8.38	8.38	8.38	8.38
# of countries	162	162	162	161	161	161	162	162	162
Observations	1,388	1,378	1,377	1,388	1,378	1,377	1,388	1,378	1,377
	Panel B: By product categories								
Ln T^{PP}	-0.691***	-0.017	-0.332***	-0.670***	-0.042	-0.320***	-0.558***	-0.181*	-0.273***
	(0.122)	(0.166)	(0.054)	(0.122)	(0.168)	(0.053)	(0.087)	(0.098)	(0.044)
Ln T^{MQ}	0.165***	0.022	0.094***	0.172***	0.034	0.100***	0.159***	0.073	0.073***
	(0.062)	(0.095)	(0.030)	(0.061)	(0.090)	(0.029)	(0.041)	(0.061)	(0.020)
Ln T^{LT}	-0.868***	-1.539***	-0.237***	-0.810***	-1.466***	-0.242***	-0.386**	-0.941***	-0.106*
	(0.191)	(0.259)	(0.081)	(0.190)	(0.253)	(0.080)	(0.151)	(0.159)	(0.055)
Ln T^{HT}	0.924***	0.984***	0.296***	0.856***	0.915***	0.294***	0.469***	0.660***	0.204***
	(0.160)	(0.311)	(0.059)	(0.163)	(0.303)	(0.058)	(0.151)	(0.202)	(0.038)
Mean of DV	8.38	8.38	8.40	8.38	8.39	8.40	8.38	8.38	8.40
# of countries	162	162	162	161	161	161	162	162	162
Observations	1,386	1,376	1,348	1,386	1,376	1,348	1,386	1,376	1,345

Notes: *,**,*** denote 10%, 5%, and 1% levels of significance, respectively. Robust standard errors, in parentheses, are clustered at the country level. All trade and income variables are five-year non-overlapping averages. All specifications additionally control for the country's institutional quality and the log of population as well as fixed effects specified in the column sub-headings. The first-stage *F*-stats for all excluded instruments are ≥ 153.70.

Table A6: Robustness to using semi-decennial, decennial, and semi-centennial data (1962-2019)

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	ln(Real GDP per capita)								
	Semi-decennial			Decennial			Semi-centennial		
	Total Trade	Imports	Exports	Total Trade	Imports	Exports	Total Trade	Imports	Exports
	Panel A: All products								
Ln T^{TT}	0.052	-0.441**	0.283***	0.055	-0.435**	0.290***	0.135	-0.256	0.301***
	(0.156)	(0.220)	(0.101)	(0.157)	(0.208)	(0.105)	(0.149)	(0.184)	(0.088)
Mean of DV	8.49	8.50	8.49	8.52	8.53	8.53	8.62	8.62	8.62
# of countries	158	158	158	157	157	157	122	122	122
Observations	629	623	625	619	614	615	158	158	158
	Panel B: By product categories								
Ln T^{PP}	-0.650***	-0.104	-0.336***	-0.673***	-0.096	-0.335***	-0.365**	-0.191	-0.249***
	(0.130)	(0.179)	(0.054)	(0.134)	(0.187)	(0.053)	(0.154)	(0.176)	(0.066)
Ln T^{MQ}	0.166***	0.071	0.104***	0.170***	0.027	0.100***	0.218***	0.170*	0.082**
	(0.062)	(0.099)	(0.029)	(0.061)	(0.091)	(0.030)	(0.067)	(0.100)	(0.034)
Ln T^{LT}	-0.828***	-1.386***	-0.234**	-0.737***	-1.339***	-0.172**	-0.584**	-0.987***	-0.028
	(0.224)	(0.285)	(0.093)	(0.200)	(0.302)	(0.085)	(0.254)	(0.334)	(0.106)
Ln T^{HT}	0.807***	0.792***	0.318***	0.768***	0.815***	0.297***	0.562***	0.590**	0.215***
	(0.172)	(0.292)	(0.061)	(0.156)	(0.275)	(0.061)	(0.197)	(0.273)	(0.067)
Ln(Population)	-0.288***	-0.343***	-0.156***	-0.281***	-0.334***	-0.144***	-0.172***	-0.232***	-0.099*
	(0.052)	(0.070)	(0.043)	(0.051)	(0.071)	(0.042)	(0.060)	(0.072)	(0.050)
Institutional Quality	1.544***	1.610***	1.475***	1.508***	1.632***	1.431***	1.825***	1.683***	1.626***
	(0.218)	(0.214)	(0.239)	(0.216)	(0.216)	(0.244)	(0.267)	(0.267)	(0.283)
Mean of DV	8.49	8.50	8.54	8.52	8.53	8.58	8.62	8.62	8.66
# of countries	158	158	155	157	157	154	122	122	120
Observations	629	623	602	619	614	593	158	158	153

Notes: *,**,*** denote 10%, 5%, and 1% levels of significance, respectively. Robust standard errors, in parentheses, are clustered at the country level. All trade and income variables are five-year, ten-year, or sixty-year non-overlapping intervals. All specifications additionally control for the country's institutional quality and the log of population as well as year and region fixed effects. The first-stage *F*-stats for all excluded instruments are ≥ 100.70.

Table A7: The relationship between income and growth in first differences (1962-2019)

	(1)	(2)	(3)	(4)	(5)	(6)
	Δ **Ln(Real GDP per capita)**					
	Total Trade		Imports		Exports	
	Panel A: OLS estimates					
$\Delta(T^{TT})$	-0.007		-0.034		0.019	
	(0.017)		(0.030)		(0.039)	
$\Delta(T^{PP})$		-0.493***		-1.126***		-0.403**
		(0.128)		(0.341)		(0.170)
$\Delta(T^{MQ})$		0.124		-0.344		0.189*
		(0.088)		(0.222)		(0.097)
$\Delta(T^{LT})$		-0.047		-0.153		-0.048
		(0.063)		(0.117)		(0.086)
$\Delta(T^{HT})$		0.176***		0.401***		0.219**
		(0.052)		(0.103)		(0.087)
Mean of DV	0.09	0.09	0.09	0.09	0.09	0.09
# of countries	171	171	171	171	171	171
Observations	1,540	1,540	1,540	1,540	1,540	1,540
	Panel A: 2SLS estimates					
$\Delta(T^{TT})$	-0.024		-0.046		-0.043	
	(0.023)		(0.042)		(0.048)	
$\Delta(T^{PP})$		-0.155		-0.534		-0.031
		(0.182)		(0.454)		(0.222)
$\Delta(T^{MQ})$		0.056		-0.285		0.096
		(0.084)		(0.324)		(0.089)
$\Delta(T^{LT})$		-0.218**		-0.441*		-0.226*
		(0.091)		(0.226)		(0.117)
$\Delta(T^{HT})$		0.321***		0.564***		0.366*
		(0.097)		(0.194)		(0.199)
Mean of DV	0.09	0.09	0.09	0.09	0.09	0.09
# of countries	171	171	171	171	171	171
Observations	1,540	1,540	1,540	1,540	1,540	1,540

Notes: *,**,*** denote 10%, 5%, and 1% levels of significance, respectively. Robust standard errors, in parentheses, are clustered at the country level. All trade and income variables are five-year non-overlapping averages. All specifications additionally control for the country's institutional quality and the log of population as well as year and region fixed effects. The first-stage *F*-stats for all excluded instruments are ≥ 9.25.

The estimates with TFP as the dependent variable are presented in Table A8. We get the same principal results as the baseline regressions except that the absolute value of the coefficients are smaller than in the baseline regressions, particularly the coefficient of the exports of primary products. The low significance of primary products in the TFP estimates is likely to be the aforementioned positive bias in TFP estimates that exclude population growth drags. Like the baseline regressions, the coefficient of high-tech imports is significantly positive, while the coefficients of low-tech trade and imports are significantly negative. These results suggest that even outside steady state, in which per capita income is also affected by capital accumulation,trade, at least to some extent, affects productivity through the technology channel.

Table A8: The effect of trade on total factor productivity and innovations

	(1)	(2)	(3)	(4)	(5)	(6)
	Ln(TFP at constant national prices), (TFP$_{2017}=1$)					
	Total Trade		Imports		Exports	
Ln T^{TT}	-0.034		-0.075*		-0.001	
	(0.035)		(0.043)		(0.028)	
Ln T^{PP}		-0.055*		0.047		-0.036**
		(0.033)		(0.041)		(0.017)
Ln T^{MQ}		0.047**		-0.010		0.023**
		(0.021)		(0.026)		(0.010)
Ln T^{LT}		-0.132*		-0.313***		-0.030
		(0.067)		(0.080)		(0.031)
Ln T^{HT}		0.053		0.187***		-0.018
		(0.056)		(0.060)		(0.021)
Mean of DV	-0.05	-0.05	-0.05	-0.05	-0.05	-0.05
# of countries	114	114	114	114	114	114
Observations	1,064	1,064	1,060	1,058	1,056	1,051
	Ln(Patent Intensity)					
	Total Trade		Imports		Exports	
Ln T^{TT}	-0.549		-0.957**		-0.065	
	(0.351)		(0.375)		(0.254)	
Ln T^{PP}		-0.707***		-0.537		-0.298***
		(0.204)		(0.342)		(0.107)
Ln T^{MQ}		-0.004		0.200		0.027
		(0.124)		(0.153)		(0.061)
Ln T^{LT}		-0.951**		-0.407		-0.527**
		(0.456)		(0.508)		(0.238)
Ln T^{HT}		0.732**		-0.380		0.455***
		(0.359)		(0.583)		(0.150)
Mean of DV	-11.18	-11.18	-11.17	-11.17	-11.18	-11.17
# of countries	137	137	136	136	137	137
Observations	807	807	804	804	803	801

Notes: *,**,*** denote 10%, 5%, and 1% levels of significance, respectively. Robust standard errors, in parentheses, are clustered at the country level. All trade and income variables are five-year non-overlapping averages. All specifications additionally control for the country's institutional quality and the log of population as well as year and region fixed effects. The first-stage *F*-stats for all excluded instruments are ≥ 113.94.

Table A9: The effect of trade on income of rich countries (2SLS)

VARIABLES	(1)	(2)	(3)	(4)	(5)	(6)
	ln(Real GDP per capita)					
	North-North			**North-all**		
	Total Trade	Imports	Exports	Total Trade	Imports	Exports
	Panel A: All products					
Ln T^{TT}	-0.135	-0.254**	-0.023	-0.212**	-0.335***	-0.075
	(0.107)	(0.114)	(0.088)	(0.102)	(0.108)	(0.095)
Mean of DV	10.27	10.27	10.27	10.27	10.27	10.27
# of countries	38	38	38	38	38	38
Observations	368	368	366	368	368	366
	Panel B: By product categories					
Ln T^{PP}	-0.238*	-0.503***	-0.061	-0.152	-0.372*	-0.013
	(0.131)	(0.159)	(0.052)	(0.156)	(0.188)	(0.065)
Ln T^{MQ}	0.325***	0.086	0.209***	0.123	-0.252*	0.166***
	(0.058)	(0.095)	(0.032)	(0.117)	(0.129)	(0.035)
Ln T^{LT}	0.017	0.634*	-0.317***	-0.469	0.537	-0.445***
	(0.263)	(0.347)	(0.094)	(0.315)	(0.342)	(0.132)
Ln T^{HT}	-0.215	-0.526*	0.185**	0.242	-0.263	0.222**
	(0.273)	(0.262)	(0.086)	(0.312)	(0.254)	(0.101)
Mean of DV	10.27	10.27	10.27	10.27	10.27	10.27
# of countries	38	38	38	38	38	38
Observations	368	368	366	368	368	366

Notes: *,**,*** denote 10%, 5%, and 1% levels of significance, respectively. Robust standard errors, in parentheses, clustered at the country level. All trade and income variables are five-year non-overlapping averages. All specifications additionally control for population and institutional quality as well as year and region fixed effects. The first-stage *F*-stats for all excluded instruments are ≥ 29.85.

Table A10: The effect of lagged trade on the gross enrollment rate (1962-2010)

	(1)	(2)	(3)	(4)	(5)	(6)
	Weighted Gross Enrollment Rate					
	Total Trade		Imports		Exports	
Ln $T^{TT}_{(t-1)}$	0.470		-1.257		1.004*	
	(0.785)		(0.887)		(0.522)	
Ln $T^{PP}_{(t-1)}$		-1.873***		0.461		-0.914***
		(0.579)		(0.667)		(0.272)
Ln $T^{MQ}_{(t-1)}$		0.988***		0.159		0.484***
		(0.350)		(0.382)		(0.153)
Ln $T^{LT}_{(t-1)}$		-1.134		-5.749***		0.015
		(0.955)		(1.410)		(0.494)
Ln $T^{HT}_{(t-1)}$		1.611*		3.979***		0.659**
		(0.821)		(1.274)		(0.290)
Ln(Population)	-0.078	-0.588**	-0.411	-1.007***	-0.064	-0.344*
	(0.202)	(0.234)	(0.268)	(0.325)	(0.172)	(0.185)
Institutional Quality	3.052***	3.533***	3.311***	2.614***	2.942***	3.053***
	(1.043)	(0.899)	(1.019)	(0.995)	(1.010)	(0.885)
Ln(Compulsory School Years)	2.438*	1.483	2.517*	2.399*	2.105*	0.695
	(1.340)	(1.147)	(1.358)	(1.225)	(1.264)	(1.185)
Mean of DV	24.56	24.56	24.57	24.57	24.61	24.68
# of countries	142	142	142	142	141	140
Observations	714	713	712	712	709	701

Notes: *,**,*** denote 10%, 5%, and 1% levels of significance, respectively. Robust standard errors, in parentheses, are clustered at the country level. All trade and GER variables are five-year non-overlapping averages. All specifications control for year and region fixed effects. The first-stage *F*-stats for all excluded instruments are ≥ 169.65.

Table A11: The effect of trade on income, using ISIC R&D classification (1988-2019)

VARIABLES	(1)	(2)	(3)	(4)	(5)	(6)
	Ln(Real GDP per capita)					
	Total Trade		Imports		Exports	
Ln T^{TT}	0.184		0.250***		-0.247	
	(0.173)		(0.082)		(0.207)	
Ln T^{PP}		-0.701***		-0.218		-0.331***
		(0.102)		(0.148)		(0.047)
Ln T^{MQ}		0.104**		0.055		0.055**
		(0.046)		(0.049)		(0.026)
Ln T^{LT}		-0.674***		-1.096***		-0.203*
		(0.230)		(0.288)		(0.106)
Ln T^{MHT}		0.331		-0.261		0.124
		(0.245)		(0.307)		(0.076)
Ln T^{HT}		0.415***		0.823***		0.178***
		(0.131)		(0.180)		(0.059)
log (Pop_reporter)	-0.074	-0.227***	-0.079	-0.343***	-0.129**	-0.116**
	(0.050)	(0.054)	(0.054)	(0.067)	(0.055)	(0.047)
Institutional Quality	1.810***	1.235***	1.962***	1.151***	1.859***	1.342***
	(0.274)	(0.229)	(0.252)	(0.245)	(0.266)	(0.251)
Mean of DV	8.63	8.63	8.72	8.63	8.64	8.70
# of countries	157	157	150	156	156	152
Observations	3,456	3,461	3,241	3,441	3,437	3,293

Notes: *,**,*** denote 10%, 5%, and 1% levels of significance, respectively. Robust standard errors, in parentheses, are clustered at the country level. All trade and income variables are five-year non-overlapping averages. All specifications additionally control for the country's institutional quality and the log of population as well as year and region fixed effects. The first-stage *F*-stats for all excluded instruments are ≥ 212.68.
In our baseline analysis, there are four main categories where medium-tech and high-tech are treated as one category while, in this analysis medium-tech and high-tech are taken separately as two categories following the OECD classification. The MHT (Medium-high-tech) category is found to be insignificant in most of the cases, which is consistent with the alternative classification that we show in Table A2.

Table A12: Robustness to accounting for FDI and migration (10-year averages: 1962-2010)

	(1)	(2)	(3)	(4)	(5)	(6)
	Weighted Gross Enrolment Rate					
	Total Trade		Imports		Exports	
Ln T^{TT}	0.836		-0.905		0.918*	
	(0.670)		(0.807)		(0.514)	
Ln T^{PP}		-1.719***		0.772		-0.858***
		(0.616)		(0.836)		(0.282)
Ln T^{MQ}		1.078***		0.232		0.496***
		(0.312)		(0.428)		(0.163)
Ln T^{LT}		-0.777		-5.284***		0.135
		(1.108)		(1.285)		(0.493)
Ln T^{HT}		1.253		3.272***		0.530*
		(0.855)		(1.142)		(0.320)
Ln(Migration/pop)	0.609**	0.460*	0.569**	0.468*	0.595**	0.383
	(0.263)	(0.274)	(0.242)	(0.241)	(0.260)	(0.286)
Ln(Net FDI as % of GDP)	-0.006	0.039	0.247	0.258	-0.035	-0.053
	(0.222)	(0.214)	(0.258)	(0.245)	(0.217)	(0.214)
Ln(Population)	0.312	-0.276	0.020	-0.681**	0.240	-0.078
	(0.232)	(0.267)	(0.265)	(0.325)	(0.218)	(0.236)
Institutional Quality	3.487***	4.063***	3.794***	2.918**	3.494***	3.786***
	(1.160)	(1.067)	(1.184)	(1.148)	(1.117)	(1.081)
Ln(Compulsory School Years)	2.389**	1.738*	2.440**	2.442**	2.171**	1.508*
	(1.091)	(0.897)	(1.126)	(1.070)	(1.024)	(0.878)
Mean of DV	22.29	22.29	22.33	22.33	22.33	22.45
# of countries	139	139	139	139	138	136
Observations	325	325	323	323	324	319
	Ln(Total Fertility Rate)					
	Total Trade		Imports		Exports	
Ln T^{TT}	-0.078		-0.079		-0.037	
	(0.050)		(0.054)		(0.032)	
Ln T^{PP}		0.194***		0.034		0.081***
		(0.036)		(0.047)		(0.016)
Ln T^{MQ}		0.013		-0.046		0.007
		(0.017)		(0.031)		(0.008)
Ln T^{LT}		-0.045		0.007		-0.013
		(0.064)		(0.085)		(0.025)
Ln T^{HT}		-0.198***		-0.056		-0.081***
		(0.072)		(0.096)		(0.025)
Ln(Migration/pop)	-0.023	-0.004	-0.025	-0.017	-0.023	0.005
	(0.021)	(0.021)	(0.021)	(0.022)	(0.021)	(0.020)
Ln(Net FDI as % of GDP)	0.000	-0.000	-0.001	0.000	-0.007	-0.014
	(0.017)	(0.017)	(0.016)	(0.015)	(0.017)	(0.013)
Ln(Population)	-0.024	-0.007	-0.028	-0.006	-0.016	0.010
	(0.019)	(0.018)	(0.021)	(0.025)	(0.018)	(0.015)
Institutional Quality	-0.368***	-0.317***	-0.369***	-0.349***	-0.366***	-0.219***
	(0.074)	(0.066)	(0.074)	(0.074)	(0.074)	(0.074)
Crude Death Rate	0.014***	0.012**	0.013***	0.011**	0.014***	0.006
	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)	(0.004)
Mean of DV	1.23	1.23	1.23	1.23	1.23	1.21
# of countries	161	161	161	161	161	161
Observations	581	581	577	577	578	563

Notes: *,**,*** denote 10%, 5%, and 1% levels of significance, respectively. Robust standard errors, in parentheses, are clustered at the country level. All trade, GER, and fertility variables are ten-year non-overlapping averages for the period 1962-2010. Immigration/pop is instrumented following Bahar and Rapoport (2018). All specifications control for year and region fixed effects. The first-stage *F*-stats for all excluded instruments are ≥ 197.58.

Table A13: The effects of trade on GER and TFR using out-of-sample predictions

	(1)	(2)	(3)	(4)	(5)	(6)
	Weighted Gross Enrolment Rate					
	Total Trade	Imports	Exports	Total Trade	Imports	Exports
	In Sample Predictions			Out of Sample Predictions		
Ln T^{PP}	-1.788***	0.389	-0.881***	-1.794***	0.364	-0.874***
	(0.548)	(0.653)	(0.261)	(0.549)	(0.651)	(0.259)
Ln T^{MQ}	1.042***	0.287	0.469***	1.046***	0.326	0.466***
	(0.312)	(0.360)	(0.145)	(0.308)	(0.369)	(0.145)
Ln T^{LT}	-1.112	-5.585***	0.074	-1.068	-5.473***	0.086
	(0.933)	(1.284)	(0.488)	(0.928)	(1.244)	(0.490)
Ln T^{HT}	1.511**	3.601***	0.690***	1.453**	3.544***	0.691***
	(0.713)	(1.076)	(0.260)	(0.717)	(1.089)	(0.258)
Ln(Population)	-0.512**	-0.960***	-0.277	-0.020	-0.315	-0.026
	(0.216)	(0.299)	(0.178)	(0.191)	(0.238)	(0.171)
Institutional Quality	3.730***	2.860***	3.223***	3.274***	3.474***	3.217***
	(0.848)	(0.932)	(0.865)	(1.002)	(0.982)	(0.971)
Ln(Compulsory School Years)	1.365	2.089**	0.810	2.252**	2.427**	1.818*
	(0.962)	(1.017)	(0.988)	(1.123)	(1.149)	(1.068)
Mean of DV	24.41	24.44	24.52	24.41	24.44	24.52
# of countries	143	143	141	143	143	141
Observations	739	736	729	739	736	729
	Ln(Total Fertility Rate)					
	Total Trade	Imports	Exports	Total Trade	Imports	Exports
	In Sample Predictions			Out of Sample Predictions		
Ln T^{PP}	0.169***	0.005	0.080***	0.168***	0.001	0.080***
	(0.015)	(0.021)	(0.007)	(0.015)	(0.022)	(0.007)
Ln T^{MQ}	0.011	-0.047***	0.013***	0.011	-0.048***	0.013***
	(0.008)	(0.011)	(0.004)	(0.008)	(0.011)	(0.004)
Ln T^{LT}	-0.075***	0.072**	-0.029**	-0.075***	0.077**	-0.028**
	(0.027)	(0.036)	(0.011)	(0.027)	(0.036)	(0.011)
Ln T^{HT}	-0.167***	-0.094***	-0.091***	-0.168***	-0.092***	-0.091***
	(0.025)	(0.030)	(0.008)	(0.025)	(0.030)	(0.008)
Ln(Population)	-0.007	0.010	0.011**	-0.008	0.011	0.011**
	(0.006)	(0.008)	(0.005)	(0.006)	(0.008)	(0.005)
Institutional Quality	-0.287***	-0.321***	-0.178***	-0.287***	-0.321***	-0.177***
	(0.029)	(0.029)	(0.030)	(0.029)	(0.029)	(0.030)
Crude death rate	0.009***	0.008***	0.003	0.009***	0.008***	0.003
	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)
Mean of DV	1.13	1.12	1.11	1.13	1.12	1.11
# of countries	164	164	164	164	164	164
Observations	1,445	1,435	1,403	1,445	1,435	1,403

Notes: *,**,*** denote 10%, 5%, and 1% levels of significance, respectively. Robust standard errors, in parentheses, are clustered at the country level. All trade, GER, and fertility variables are five-year non-overlapping averages. All specifications control for year and region fixed effects. The first-stage *F*-stats for all excluded instruments are ≥ 165.19.

Table A14: The effect of trade and immigration, using the Frankel and Romer (1999) instrument for migration

VARIABLES	(1)	(2)	(3)	(4)	(5)	(6)
	Ln(Real GDP per capita)					
	Total Trade	Imports	Exports	Total Trade	Imports	Exports
	Does not control FDI and Migration			Controls FDI and Migration		
	Panel A: Total Trade					
Ln T^{TT}	0.142	-0.323	0.301***	0.066	-0.363**	0.202*
	(0.174)	(0.223)	(0.115)	(0.137)	(0.171)	(0.102)
Ln(FDI/GDP)				-0.007	0.056	-0.035
				(0.059)	(0.060)	(0.063)
Ln(Immigration)				0.362***	0.369***	0.348***
				(0.065)	(0.066)	(0.066)
Distance from equator				0.015**	0.012	0.014*
				(0.007)	(0.008)	(0.007)
Mean of DV	8.21	8.22	8.22	8.22	8.23	8.22
# of countries	161	161	161	159	159	159
Observations	590	585	586	555	551	552
	Panel B: Decomposed Trade					
Ln T^{PP}	-0.715***	0.108	-0.323***	-0.645***	0.229	-0.300***
	(0.114)	(0.183)	(0.056)	(0.119)	(0.174)	(0.059)
Ln T^{MQ}	0.188***	-0.088	0.104***	0.146**	-0.129	0.078**
	(0.066)	(0.112)	(0.033)	(0.064)	(0.100)	(0.033)
Ln T^{LT}	-0.801***	-1.998***	-0.198**	-0.697***	-1.760***	-0.158*
	(0.162)	(0.367)	(0.081)	(0.180)	(0.337)	(0.082)
Ln T^{HT}	0.933***	1.690***	0.263***	0.747***	1.381***	0.165**
	(0.162)	(0.421)	(0.061)	(0.159)	(0.353)	(0.064)
Ln(FDI/GDP)				0.050	0.022	0.036
				(0.055)	(0.071)	(0.049)
Ln(Immigration)				0.246***	0.290***	0.256***
				(0.060)	(0.062)	(0.058)
Distance from equator				0.010	0.015**	0.008
				(0.006)	(0.007)	(0.007)
Mean of DV	8.21	8.22	8.24	8.22	8.23	8.25
# of countries	161	161	160	159	159	158
Observations	589	585	570	555	551	537

Notes: *,**,*** denote 10%, 5%, and 1% levels of significance, respectively. Robust standard errors, in parentheses, are clustered at the country level. All trade and income variables are five-year non-overlapping averages. All specifications additionally control for log of population, the institutional quality of the country as well as year and region fixed effects. The first-stage *F*-stats for all excluded instruments are $\geq$ 27.72. The gravity equation for immigration is estimated with the cultural proximity factor used in Frankel and Romer (1999).

Table A15: The effect of trade on GDP per capita, by product category (out-of-sample estimations) (1962-2019)

	(1)	(2)	(3)	(4)	(5)	(6)
	Ln(Real GDP per capita)					
	Total Trade	Imports	Exports	Total Trade	Imports	Exports
	In-Sample Predictions			Out-of-Sample Predictions		
Ln T^{PP}	-0.691***	-0.017	-0.332***	-0.696***	-0.025	-0.334***
	(0.122)	(0.166)	(0.054)	(0.121)	(0.167)	(0.054)
Ln T^{MQ}	0.165***	0.022	0.094***	0.164**	0.015	0.094***
	(0.062)	(0.095)	(0.030)	(0.064)	(0.095)	(0.030)
Ln T^{LT}	-0.868***	-1.539***	-0.237***	-0.883***	-1.562***	-0.241***
	(0.191)	(0.259)	(0.081)	(0.189)	(0.253)	(0.082)
Ln T^{HT}	0.924***	0.984***	0.296***	0.929***	1.003***	0.294***
	(0.160)	(0.311)	(0.059)	(0.161)	(0.312)	(0.059)
Ln(Population)	-0.285***	-0.321***	-0.168***	-0.288***	-0.325***	-0.169***
	(0.051)	(0.071)	(0.040)	(0.051)	(0.071)	(0.041)
Institutional Quality	1.506***	1.597***	1.337***	1.506***	1.603***	1.343***
	(0.213)	(0.220)	(0.234)	(0.213)	(0.219)	(0.234)
Mean of DV	8.38	8.38	8.40	8.38	8.38	8.40
# of countries	162	162	162	162	162	162
Observations	1,386	1,376	1,348	1,386	1,376	1,348

Notes: *,**,*** denote 10%, 5%, and 1% levels of significance, respectively. Robust standard errors, in parentheses, are clustered at the country level. All trade and income variables are five-year non-overlapping averages. All specifications additionally control for year and region fixed effects. The first-stage *F*-stats for all excluded instruments are ≥ 219.23.

Table A16: 2SLS estimates of trade with and without the great-circle distance in the gravity equation (1962-2010)

	(1)	(2)	(3)	(4)	(5)	(6)
	Ln(Real GDP per capita)					
	Baseline			**Gravity without great-circle distance**		
	Total Trade	Imports	Exports	Total Trade	Imports	Exports
	Panel A: All products					
Ln T^{TT}	0.098	-0.415*	0.304***	0.096	-0.426*	0.306***
	(0.175)	(0.230)	(0.110)	(0.175)	(0.231)	(0.110)
Mean of DV	8.38	8.38	8.38	8.38	8.38	8.38
# of countries	162	162	162	162	162	162
Observations	1,388	1,378	1,377	1,389	1,379	1,378
	Panel B: By product category					
Ln T^{PP}	-0.691***	-0.017	-0.332***	-0.700***	-0.027	-0.332***
	(0.122)	(0.166)	(0.054)	(0.124)	(0.175)	(0.054)
Ln T^{MQ}	0.165***	0.022	0.094***	0.166***	0.027	0.095***
	(0.062)	(0.095)	(0.030)	(0.062)	(0.095)	(0.030)
Ln T^{LT}	-0.868***	-1.539***	-0.237***	-0.856***	-1.547***	-0.236***
	(0.191)	(0.259)	(0.081)	(0.197)	(0.272)	(0.082)
Ln T^{HT}	0.924***	0.984***	0.296***	0.917***	0.982***	0.294***
	(0.160)	(0.311)	(0.059)	(0.165)	(0.316)	(0.060)
Ln(Population)	-0.285***	-0.321***	-0.168***	-0.284***	-0.326***	-0.168***
	(0.051)	(0.071)	(0.040)	(0.051)	(0.072)	(0.040)
Institutional Quality	1.506***	1.597***	1.337***	1.513***	1.602***	1.345***
	(0.213)	(0.220)	(0.234)	(0.214)	(0.220)	(0.235)
Mean of DV	8.38	8.38	8.40	8.38	8.38	8.40
# of countries	162	162	162	162	162	162
Observations	1,386	1,376	1,348	1,387	1,377	1,349

Notes: *,**,*** denote 10%, 5%, and 1% levels of significance, respectively. Robust standard errors, in parentheses, are clustered at the country level. All trade and income variables are five-year non-overlapping averages. All specifications control for year and region fixed effects. The first-stage *F*-stats for all excluded instruments are ≥ 163.67.

Table A17: The effect of lagged trade on GDP per capita, by product category (2SLS estimates, 1962-2019)

	(1)	(2)	(3)	(4)	(5)	(6)
	Ln(Real GDP per capita)					
	Trade$_{t-i,i=0}$			**Trade**$_{t-i,i=1}$		
	Total Trade	Imports	Exports	Total Trade	Imports	Exports
	Panel A: All products					
Ln T^{TT}	0.098	-0.415*	0.304***	0.132	-0.376	0.321***
	(0.175)	(0.230)	(0.110)	(0.176)	(0.235)	(0.111)
Mean of DV	8.38	8.38	8.38	8.44	8.45	8.45
# of countries	162	162	162	161	161	161
Observations	1,388	1,378	1,377	1,261	1,251	1,250
	Panel B: By product categories					
Ln T^{PP}	-0.691***	-0.017	-0.332***	-0.706***	-0.012	-0.329***
	(0.122)	(0.166)	(0.054)	(0.121)	(0.162)	(0.053)
Ln T^{MQ}	0.165***	0.022	0.094***	0.165**	0.018	0.100***
	(0.062)	(0.095)	(0.030)	(0.064)	(0.097)	(0.029)
Ln T^{LT}	-0.868***	-1.539***	-0.237***	-0.863***	-1.524***	-0.243***
	(0.191)	(0.259)	(0.081)	(0.187)	(0.262)	(0.077)
Ln T^{HT}	0.924***	0.984***	0.296***	0.975***	1.026***	0.311***
	(0.160)	(0.311)	(0.059)	(0.160)	(0.327)	(0.059)
Ln(Population)	-0.285***	-0.321***	-0.168***	-0.284***	-0.315***	-0.168***
	(0.051)	(0.071)	(0.040)	(0.051)	(0.072)	(0.039)
Institutional Quality	1.506***	1.597***	1.337***	1.460***	1.531***	1.276***
	(0.213)	(0.220)	(0.234)	(0.205)	(0.218)	(0.229)
Mean of DV	8.38	8.38	8.40	8.45	8.45	8.47
# of countries	162	162	162	161	161	161
Observations	1,386	1,376	1,348	1,259	1,249	1,220

Notes: *,**,*** denote 10%, 5%, and 1% levels of significance, respectively. Robust standard errors, in parentheses, are clustered at the country level. All trade and income variables are five-year non-overlapping averages. All specifications control for year and region fixed effects. The first-stage *F*-stats for all excluded instruments are ≥ 155.48.

Table A18: Mediation analysis: Direct Effects

	(1) **Ln(GDP pc)**	(2) **GER**	(3) **Ln(TFR)**	(4) **Ln(GDP pc)**	(5) **GER**	(6) **Ln(TFR)**	(7) **Ln(GDP pc)**	(8) **GER**	(9) **Ln(TFR)**
	Total trade			Imports			Exports		
GER	0.067***			0.072***			0.082***		
	(0.014)			(0.014)			(0.014)		
Ln(TFR)	-0.157***			-0.184***			-0.066		
	(0.056)			(0.057)			(0.058)		
Ln T^{PP}	-0.496***	-3.717***	1.189***	0.007	-3.264***	0.775***	-0.253***	-1.088***	0.366***
	(0.105)	(0.591)	(0.141)	(0.119)	(0.855)	(0.225)	(0.063)	(0.266)	(0.064)
Ln T^{MQ}	0.115**	0.407	0.102	-0.101	1.125***	-0.420***	0.095***	0.132	0.098***
	(0.049)	(0.310)	(0.076)	(0.064)	(0.357)	(0.093)	(0.025)	(0.146)	(0.037)
Ln T^{LT}	-0.754***	-0.572	-0.426*	-1.160***	-2.133*	0.037	-0.219***	-0.042	-0.272***
	(0.151)	(0.913)	(0.224)	(0.234)	(1.159)	(0.329)	(0.080)	(0.447)	(0.091)
Ln T^{HT}	0.680***	6.095***	-1.515***	0.882***	7.947***	-1.482***	0.209***	2.668***	-0.677***
	(0.131)	(0.685)	(0.157)	(0.196)	(1.064)	(0.299)	(0.056)	(0.244)	(0.051)
# of countries	193	193	193	193	193	193	192	192	192
Observations	1,613	1,613	1,613	1,603	1,603	1,603	1,555	1,555	1,555

Notes: *,**,*** denote 10%, 5%, and 1% levels of significance, respectively. Robust standard errors, in parentheses, clustered at the country level. All trade and income variables are five-year non-overlapping averages. All specifications additionally control for population and institutional quality as well as year and region fixed effects. We use the *gsem* command in Stata to estimate the structural equation model laid out in Equation (12).

Table A19: Mediation analysis: Direct and indirect effects

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
					ln(Real GDP per capita)				
	Total trade			Imports			Exports		
	Direct Effect	via TFR	via GER	Direct Effect	via TFR	via GER	Direct Effect	via TFR	via GER
T^{PP}	-0.496***	-0.186***	-0.248***	0.007	-0.142***	-0.236***	-0.253***	-0.024**	-0.089***
	(0.105)	(0.033)	(0.029)	(0.119)	(0.028)	(0.033)	(0.063)	(0.011)	(0.014)
T^{MQ}	0.115**	-0.016***	0.027***	-0.101	0.077***	0.081***	0.095***	-0.007**	0.011*
	(0.049)	(0.005)	(0.010)	(0.064)	(0.014)	(0.015)	(0.025)	(0.003)	(0.006)
T^{LT}	-0.754***	0.067***	-0.038	-1.160***	-0.007	-0.154***	-0.219***	0.018**	-0.003
	(0.151)	(0.018)	(0.030)	(0.234)	(0.025)	(0.041)	(0.080)	(0.008)	(0.020)
T^{HT}	0.680***	0.237***	0.407***	0.882***	0.272***	0.574***	0.209***	0.045**	0.218***
	(0.131)	(0.041)	(0.049)	(0.196)	(0.048)	(0.070)	(0.056)	(0.020)	(0.019)

Notes: *,**,*** denote 10%, 5%, and 1% levels of significance, respectively. Robust standard errors, in parentheses, clustered at the country level. All trade and income variables are five-year non-overlapping averages. All specifications additionally control for population and institutional quality as well as year and region fixed effects. We use the *gsem* command in Stata to estimate the structural equation model laid out in Equation (12) and calculate bootstrapped standard errors for the indirect effect using the process described in Preacher and Hayes (2004).