Accommodating Emerging Giants in the Global Economy*

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Abstract

How has aggregate income and welfare in the United States been affected by globalization and rapid productivity growth in emerging economies? We use the class of constant elasticity trade models to provide quantitative evidence on these questions. We find that reductions in worldwide trade frictions over the period from 1960-2020 reduced the share of the United States in global GDP but raised its aggregate welfare. Similarly, productivity growth in Japan and China led to a decline in the relative income of the United States, but brought aggregate welfare gains from a resulting expansion in global production possibilities. Trade integration and foreign productivity growth have relatively modest effects on domestic income and welfare compared to domestic productivity growth.

Keywords: competitiveness, convergence, globalization, welfare gains from trade

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1 Introduction

History provides examples of large changes in the relative economic size of nations. Often these economic realignments coincide with heightened geopolitical tension. A historical example is the relative decline of the United Kingdom in the face of the emerging giants of Germany and the United States in the late-19th century. More recent examples include the relative decline of the United States in the wake of rapid Japanese growth after the Second World War and the emergence of China into global markets at the end of the 20th century. Is rapid growth in an emerging economy good or bad for income and welfare in other nations? What are the mechanisms through which these effects occur? How important is foreign productivity growth and trade integration for a country's income and welfare compared to its own productivity growth?

We use the class of quantitative trade models with a constant trade elasticity to provide empirical evidence on these questions. We combine this class of models with data on bilateral trade, gross domestic product (GDP) and population over the period from 1960-2020. We examine the implications of the emergence of Japan and China for the income and welfare on the United States and other nations. We show that rapid productivity growth in Japan and China led to a substantial relative economic decline in the United States, as measured by its share of global income. Nevertheless, this rapid productivity growth raised aggregate welfare in the United States, through an expansion in global production possibilities, and the resulting reduction in consumer prices. In both cases, the effects of foreign productivity growth and trade integration are modest relative to the effects of domestic productivity growth.

We begin by using the class of constant elasticity trade models to recover measures of bilateral trade frictions and productivities from observed data on bilateral trade, national income and population. We solve for the unique values of these unobserved model primitives for which the observed data are consistent with general equilibrium in this class of models (up to normalization). Using our model-inverted measures of trade frictions, we find a marked increase in trade integration from 1960-2020, which is particularly rapid during the so-called era of "hyper globalization" from the late-1980s to the Great Financial Crisis in 2008. From that date onwards, we find a slowdown ("snowbalization") and a reverse ("deglobalization") of trade integration, which is reinforced by the onset of the U.S.-China trade war in 2018. Our measure of trade frictions, which allows for asymmetric trade costs, differs substantially from the conventional Head-Ries Index, which assumes symmetric trade costs. Using our model-inverted measures of productivities, we find that Japan's productivity rapidly converges towards U.S. levels during the opening decades of our sample, before falling back from 1990 onwards. Following China's domestic liberalization in 1978, we find an acceleration in its rate of productivity growth, although it remains substantially below U.S. productivity at the end of our sample period.

Using our model-based measures of trade frictions and productivities, we undertake counterfactuals to assess the contributions of domestic productivity growth, foreign productivity growth and trade integration to changes in countries' shares of global GDP and welfare. Higher foreign productivity has three main effects on the domestic GDP share. First, there is a negative composition effect, from an increase in the size of foreign GDP in the denominator of the domestic GDP share. Second, there is a positive market size effect from an increase in foreign income, which raises the demand for domestic goods, and hence increases the domestic wage. Third, there is a negative cross-substitution effect from lower prices of foreign goods in markets around the world, which leads consumers in those markets to substitute towards foreign goods, thereby reducing the demand for domestic goods, and hence decreasing the domestic wage. Higher foreign productivity also directly reduces domestic consumer prices, thereby decreasing the domestic cost of living and raising domestic welfare. Lower trade frictions have similar effects on domestic GDP shares and welfare as higher foreign productivity, but there is now bilateral variation in the incidence of these lower trade frictions across pairs of exporters and importers. Again reductions in trade frictions affect domestic GDP shares and welfare through composition effects, market size effects, cross-substitution, and cost of living effects.

In our counterfactuals, we isolate the contributions of individual model primitives by solving for the general equilibrium of the model allowing that primitive to change over time, but holding all other model primitives constant at their values at the end of our sample period. If we allow all model primitives to change over time, we exactly reproduce the observed data. If we allow only some model primitives to change over time, the model's counterfactual predictions in general differ from the observed data. We find that the decline in the U.S. GDP share over time is largely driven by productivity catchup, in Western Europe and Japan towards the beginning of our sample period, and in China and other emerging economies towards the end of our sample period. We find that the trade integration over our sample period reduced the share of the U.S. in global GDP, through negative terms of trade effects. Other countries experienced larger reductions in their bilateral trade frictions to markets around the world than the U.S., which reduced their prices relative to those of the United States. In response, consumers substituted away from U.S. goods towards those of other countries, thereby bidding down wages in the United States relative to those in other countries. Nevertheless, we find that the United States gained in terms of welfare from these reductions in bilateral trade frictions, highlighting that changes in countries' relative incomes can be misleading for changes in their welfare.

We find that rapid productivity growth in China contributed to the decline in the U.S. share of global GDP. While this decline is partly explained by cross-substitution away from U.S. goods, as the increase in China's productivity reduces the relative price of its goods in markets around the world, it mostly reflects the mechanical effect of China becoming bigger, as its productivity growth raises its own GDP, thereby increasing the denominator in the U.S. GDP share. Despite this negative impact on the relative economic size of the U.S., we find that Chinese productivity growth raised U.S. welfare, through the resulting reduction in consumer prices and the cost of living. We find a similar pattern for the impact of Japan's rapid productivity growth in the opening decades of our sample period on the U.S. GDP share and welfare. In both cases, we find that the impact of foreign productivity growth on domestic welfare is relatively modest compared to that of domestic productivity growth, especially for a large country such as the United States for which trade is a relatively small share of expenditure.

Our paper is related to a number of existing strands of research. First, we contribute to a lively debate about the potential threat from Chinese economic growth to living standards in the United States, including the popular books by Pillsbury (2016), Allison (2018), and Miller (2022). This debate about the potential threat from China parallels an earlier controversy about the challenges posed by the rise of Japan, including Prestowitz (1988), Thurow (1992), and Tyson (1992). It also connects with discussions of great power competition throughout history, such as the threat to Britain from the emergence of Germany and the United States in the late-19th century, as discussed in Kennedy (1987, 1988), Ferguson (2002) and Mearsheimer (2024). More broadly, this discussion is related to the debate about international competitiveness and the insight that international trade is not zero-sum, as discussed in Krugman (1994b). Relative to this research, we use the class of constant elasticity trade models to quantify the impact of globalization and foreign productivity growth on domestic income and welfare.

Second, our work connects with theoretical research on the impact of growth in low and middle-income countries on income and welfare in high-income countries. In neoclassical trade theory, growth in one country affects income and welfare in another country through the terms of trade. In general, foreign productivity growth can either raise or reduce domestic welfare depending on whether it is export or import-biased (e.g., Hicks 1953, Johnson 1955, and Krugman 1994c). We provide empirical evidence on the magnitude of these terms of trade effects from rapid productivity growth in China and Japan in the second half of the 20th century, using the class of quantitative trade models with a constant trade elasticity.

Third, we build on research on this class of quantitative trade models, including models of country product differentiation (Armington 1969); Ricardian technology differences (Eaton and Kortum 2002); firm love of variety and increasing returns to scale (Krugman 1980); and heterogeneous firms (Melitz 2003 and Chaney 2008). Models within this class consider posit different reasons for trade (e.g., comparative advantage versus increasing returns to scale); assume different sources of the welfare gains from trade (e.g., consumption gains versus both consumption and production gains); and make different assumptions about preferences, technology and market structure (e.g., perfect competition and constant returns to scale versus monopolistic competition and increasing returns to scale). Nevertheless, under the appropriate assumptions on preferences, technology and market structure (e.g. constant elasticity of substitution (CES) demand and a Pareto productivity distribution for heterogeneous firm models), each of these models falls within the class considered by Arkolakis et al. (2012), in which bilateral trade between countries is characterized by a gravity equation, with a constant partial elasticity of bilateral trade flows with respect to bilateral trade costs.

This class of quantitative trade models is rich enough to connect directly to the observed data, such as many heterogeneous countries that differ in productivity and bilateral trade costs. Nevertheless, these models remain tractable and amenable to a theoretical analysis of their properties, including the existence and uniqueness of the equilibrium. In contrast to earlier computable general equilibrium (CGE) models, these quantitative trade models have only a small number of structural parameters to estimate. Therefore, they lend themselves to credible identification of these parameters, using quasi-experimental sources of exogenous variation. Since these models are able to rationalize the observed data as an equilibrium, they can be used to undertake counterfactuals for the impact of empirically-relevant shocks and public policy interventions (such as rapid productivity growth in an emerging economy or globalization).

In this class of quantitative trade models, counterfactuals can be undertaken in the full non-linear model using assumed relative changes for model primitives and the observed values of the endogenous variables in an initial equilibrium. These counterfactuals are often referred to as "exact-hat algebra" counterfactuals, where the "hat" refers to the assumed relative changes in fundamentals, and the "exact" refers to the solution of the full non-linear model (see Dekle et al. 2007 and Costinot and Rodríguez-Clare 2014). Additionally, these quantitative trade models lend themselves to a sufficient statistics representation in terms of reduced-form parameters that are common across models within this class and observed variables such as expenditure shares. This sufficient statistics representation holds for both the welfare gains from trade in the full non-linear model (Arkolakis et al. 2012) and for the first-order impact of productivity and trade cost shocks (e.g., Baqaee and Farhi 2024, Kleinman et al. 2024, and Huo et al. 2025). A related empirical literature has used the gravity equation in this class of models to measure bilateral trade frictions, including Head and Ries (2001) and Head and Mayer (2021).

Within this literature on quantitative trade models, we connect most closely with other research that has examined the effect of China's rapid economic growth on other countries. di Giovanni et al. (2014) and Hsieh and Ossa (2016) use multi-country, multi-industry models of trade to evaluate the impact of China's trade integration and productivity growth on other countries' welfare from the 1990s onwards. Adão et al. (2017) uses a nonparametric neoclassical trade model to estimate the welfare gains from China's trade integration over the period from 1995-2010. Relative to these studies, we consider a simpler model structure of a single sector with a constant trade elasticity. We develop a new approach to recovering bilateral trade frictions and country productivities that only requires data on bilateral trade, national income and population. Our simpler model structure and more minimal data requirements allow us to implement our approach over a much longer time horizon from 1960-2020. We are thus able to explore the long-run impact of productivity growth and trade integration and compare and contrast the effects of the recent emergence of China with those of the earlier emergence of Japan.

Fourth, our work connects with a growing body of research on geoeconomics or the international political economy of trade policy, including Hirschman (1945), Tinbergen (1962), Broner et al. (2024), Clayton et al. (2023), Thoenig (2023), Becko and O'Connor (2024), Clayton et al. (2024), Kleinman et al. (2024), Liu and Yang (2024), and Becko et al. (2025). This research studies how economic size translates into international political power. This international political power can be used to influence economic decisions in trade partners, through for example threats of trade policies or sanctions. In contrast, we focus on the economic effects of rapid productivity growth in large emerging economies on the income and welfare of other countries.

Any model is necessarily an abstraction and hence it is appropriate to discuss caveats and limitations. We focus on a single-sector model and hence abstract from heterogeneity across industries (see Costinot et al. 2012 and Ossa 2016 for multi-industry extensions). We abstract from input-output linkages, which typically magnify the welfare gains from trade, and non-traded goods, which typically dampen the welfare gains from trade (see for example Caliendo and Parro 2015). We develop a model of equipped labor, in which labor is the sole factor of production. Therefore, capital accumulation is absorbed into productivity (see Alvarez 2017 and Kleinman et al. 2023a for analyses of capital accumulation), and we abstract from endogenous technological change (see Grossman and Helpman 1995 for a review). We consider a static trade model without an intertemporal consuming-saving decisions and treat the ratio of expenditure to income as exogenous (see Kleinman et al. 2023b for analysis of endogenous current accounts and international capital flows). Finally, we assume a representative agent within each country, such that we abstract from distributional consequences of international trade within countries (see Autor et al. 2013, Waugh 2018, Caliendo et al. 2019 and Galle et al. 2023). We abstract from these considerations, not because we think that they are unimportant, but in order to quantify the insights of the standard workhorse model of international trade for effects of productivity growth and globalization on income and welfare around the globe.

The remainder of the paper is structured as follows. Section 2 outlines the class of conventional constant elasticity trade models and characterizes the mechanisms through which productivity growth and trade integration affect income and welfare. Section 3 discusses the data and the parameterization of this class of models. Section 4 discusses our model inversion to measure the evolution of bilateral trade frictions and productivities over time. Section 5 introduces our counterfactuals to assess the contributions of domestic productivity growth, foreign productivity growth and globalization to aggregate income and welfare.

2 Theoretical Framework

The world economy consists of many countries indexed by $i, n \in \{1, \ldots, N\}$. For expositional simplicity, we focus on the Armington (1969) model, in which goods are differentiated by country of origin. But all of our results hold throughout the class of quantitative trade models with a constant trade elasticity, including Eaton and Kortum (2002), Krugman (1980), and Melitz (2003) with a Pareto productivity distribution. Throughout the following we use bold math font to denote vectors or matrices. We omit the time subscript to streamline the notation, but it is taken as understood that all variables are allowed to vary over time.

2.1 Preferences, Endowments and Technology

Each country n has an exogenous supply of labor ℓ_n. The preferences of the representative consumer in country n ($\mathcal{U}_n$) are defined over the consumption of the good produced by each country i (c_{ni}), and are assumed to take the following constant elasticity of substitution (CES) form:

$$\mathcal{U}_n = \left[\sum_{i=1}^{N} c_{ni}^{\frac{\theta}{\theta+1}} \right]^{\frac{\theta+1}{\theta}}, \qquad \theta = \sigma - 1 > 0, \tag{1}$$

where $\theta > 0$ is the trade elasticity and $\sigma > 1$ is the elasticity of substitution between country varieties.

Goods are produced with labor according to a constant returns to scale production technology. If country i employs ℓ_i units of labor, y_i units of output are produced:

$$y_i = z_i \ell_i, \tag{2}$$

where z_i denotes productivity. This production technology corresponds to a specification with equipped labor, in which physical capital is absorbed into productivity (z_i).

Trade between countries is subject to iceberg variable trade costs, such that $\tau_{ni} \geq 1$ units of a good must be shipped from country i to country n in order for one unit to arrive (where we assume $\tau_{ni} > 1$ for $n \neq i$ and $\tau_{nn} = 1$).

2.2 Market Equilibrium

Markets are perfectly competitive. Profit maximization and zero profits imply that the price faced by the representative consumer in market n for the good produced by country i is equal to the marginal cost of supplying that market inclusive of trade costs:

$$p_{ni} = \frac{\tau_{ni} w_i}{z_i}. \tag{3}$$

Expenditure minimization implies that the price index dual to the utility function (1) takes the following form:

$$\mathcal{P}_n = \left[\sum_{n=1}^{N} p_{ni}^{-\theta} \right]^{-\frac{1}{\theta}}. \tag{4}$$

From Shephard's Lemma, country n's share of expenditure on goods produced in country i is:

$$s_{ni} = \frac{p_{ni}^{-\theta}}{\sum_{h=1}^{N} p_{nh}^{-\theta}}. \tag{5}$$

Income accounting requires that country i's income is equal to the sum across all markets n of expenditure on its goods:

$$w_i \ell_i = \sum_{n=1}^{N} \frac{\left(\tau_{ni} w_i / z_i\right)^{-\theta}}{\sum_{h=1}^{N} \left(\tau_{nh} w_h / z_h\right)^{-\theta}} e_n w_n \ell_n, \tag{6}$$

where we have substituted for the expenditure share (s_{ni}) using equation (5) and substituted for prices (p_{ni}) using the pricing rule (3); and $e_n = 1 + (d_n / w_n l_n)$ denotes the ratio of expenditure to income, where d_n is the trade deficit. We follow the quantitative international trade literature in treating trade deficits as exogenous. We define $q_i \equiv w_i \ell_i$ as country gross domestic product (GDP).

General equilibrium in this class of trade models with a constant trade elasticity reduces to solving for the N wages in each country (w_n) such that the system of N equations (6) holds. From this solution for wages, we can recover the equilibrium values of all other endogenous variables. Since wages are gross substitutes in the system of equations (6), there exists a unique wage vector (up to a choice of numeraire) that solves this system of equations, as shown in Alvarez and Lucas (2007) and Allen et al. (2020). We choose the convenient numeraire that world GDP is equal to one: $\sum_{i=1}^{N} q_i = 1$. Defining $\boldsymbol{Q}$ as the matrix with the nominal income row vector q' stacked N times, this choice of numeraire implies $\boldsymbol{Q} d \ln \boldsymbol{q} = 0$.

Having solved for wages in general equilibrium from the income accounting relationship (6), and using the price index (4) and expenditure share (5), we can express country real income in the following indirect form:

$$\mathcal{U}_n = \frac{w_n}{\mathcal{P}_n} = \frac{w_n}{\left[\sum_{h=1}^{N} \left(\tau_{nh} w_h / z_h\right)^{-\theta}\right]^{-\frac{1}{\theta}}} = z_n \left(\frac{1}{s_{nn}}\right)^{\frac{1}{\theta}}, \tag{7}$$

where we have used $\tau_{nn} = 1$.

Therefore, each country's real income can be expressed in equation (7) in terms of its own productivity (z_n), and its market access to trade partners, as summarized by its endogenous domestic trade share (s_{nn}). The lower a country's trade costs to its foreign partners (τ_{ni} for $n \neq i$), the lower the domestic trade share (s_{nn}), and the higher a country's real income ($w_n/\mathcal{P}_n$). This representation in equation (7) highlights the central role of domestic productivity (z_n) in driving domestic welfare and that shocks to foreign productivity (z_i for $i \neq n$) and trade costs (τ_{ni}) affect domestic welfare through the domestic trade share (s_{nn}).

The key exogenous primitives in the model are productivity (z_n), trade costs (τ_{ni}), population shares (ℓ_n) and the ratio of expenditure to income (e_n). Given these exogenous primitives, we can solve for wages (w_n) from the system of general equilibrium conditions (6). From these solutions for wages, we can recover all other endogenous variables, including expenditure shares (s_{ni}) and real income ($w_n/\mathcal{P}_n$).

In general, the assumption of exogenous productivity (z_n) can be relaxed to introduce capital accumulation (e.g., Alvarez 2017 and Kleinman et al. 2023a) and/or endogenous innovation (e.g., Grossman and Helpman 1995). Similarly, the assumption of an exogenous ratio of expenditure to income (e_n) can be relaxed to introduce a consumption-saving decision and endogenous current accounts (e.g., Reyes-Heroles 2016, Eaton et al. 2016, and Kleinman et al. 2023b). We make both assumptions to quantify the effects of foreign productivity growth and trade liberalization using the standard workhorse model of international trade.

2.3 Mechanisms

To provide further intuition for the mechanisms through which foreign productivity growth and trade liberalization affect domestic income and welfare, we linearize the general equilibrium conditions of the model using the matrix representation of Kleinman et al. (2024).

2.3.1 Foreign Productivity Growth

We begin by totally differentiating the income accounting relationship (6) and welfare (7), holding constant bilateral trade costs (τ_{ni}), population (ℓ_n), and the expenditure-income ratio (e_n), but allowing productivity (z_n) in each country to change. We obtain the following matrix representation of the first-order general equilibrium impact of changes in productivity in each country on the income and welfare of all countries:

$$\underbrace{\mathrm{d}\ln \mathbf{w}}_{\text{income effect}} = \underbrace{\mathbf{T}\,\mathrm{d}\ln \mathbf{w}}_{\substack{\text{market-size}\\ \text{effect}}} + \underbrace{\theta \mathbf{M}\left(\mathrm{d}\ln \mathbf{w} - \mathrm{d}\ln \boldsymbol{z}\right)}_{\substack{\text{cross-substitution}\\ \text{effect}}}, \tag{8}$$

$$\underbrace{\mathrm{d}\ln\mathbf{u}}_{\text{welfare effect}} = \underbrace{\mathrm{d}\ln\mathbf{w}}_{\substack{\text{income}\\\text{effect}}} - \underbrace{\mathbf{S}\,\mathrm{d}\ln\mathbf{w}}_{\substack{\text{cost-of-living}\\\text{effect}}}, \tag{9}$$

where $\mathbf{S} \equiv [s_{ni}]$ is the $N \times N$ matrix with the ni-th element equal to importer n's share of expenditure on exporter i; $\mathbf{T} \equiv [t_{in}]$ is the $N \times N$ matrix with the in-th element equal to exporter i's share of income from importer n, with $t_{in} = \frac{s_{ni} e_n w_n \ell_n}{w_i \ell_i}$; we define $\boldsymbol{M} \equiv \boldsymbol{TS} - \boldsymbol{I}$; and we report the derivations in Online Appendix A.[1]

From equation (8), the effect of productivity growth in country n on income in country i can decomposed into (i) a market-size effect and (ii) a cross-substitution effect. The market size effect ($\mathbf{T}\,\mathrm{d}\ln\mathbf{w}$) captures the impact of the productivity shock on income in each market, where the effect of a change in income in market n on country i depends on the share of its income derived from that market (as captured by the income share matrix $\boldsymbol{T}$).

The cross-substitution effect ($\theta \cdot \mathbf{M} \times (\mathrm{d}\ln\mathbf{w} - \mathrm{d}\ln\mathbf{z})$) captures consumer substitution in each market in response to a productivity shock. This consumer substitution depends on the product of the income share and expenditure share matrices ($\boldsymbol{M} \equiv \boldsymbol{TS} - \boldsymbol{I}$), where the in-th element of the cross-substitution matrix ($\boldsymbol{M} \equiv \boldsymbol{TS} - \boldsymbol{I}$) is given by $m_{in} \equiv \sum_{h=1}^{N} t_{ih} s_{hn} - 1_{n=i}$. For $i \neq n$, the sum $\sum_{h=1}^{N} t_{ih} s_{hn}$ captures the overall competitive exposure of country i to country n, through each of their common markets h, weighted by the importance of market h for country i's income (t_{ih}). As the competitiveness of country n increases, as measured by a decline in its wage relative to its productivity ($\mathrm{d}\ln w_n - \mathrm{d}\ln z_n$), consumers in all markets h substitute towards country n and away from other countries $i \neq n$. This substitution reduces income in country i and raises it in country n. With a constant elasticity import demand system, the magnitude of this cross-substitution effect in market h depends on the trade elasticity (θ) and the share of expenditure in market h on the goods produced by country n (s_{hn}): consumers in market h increase expenditure on country n by $(s_{hn} - 1)$ and lower expenditure on country i by s_{hn}. Summing across all markets h, we obtain the overall impact on country i's income.

Comparing equations (8) and (9), the change in welfare ($\mathrm{d}\ln\mathbf{u}$) in response to a productivity shock depends on the change in income ($\mathrm{d}\ln\mathbf{w}$) and a cost-of-living effect that captures the change in the cost of living ($\mathbf{S}\,(\mathrm{d}\ln\mathbf{w} - \mathrm{d}\ln\mathbf{z})$). This change in the cost of living in country n in turn depends on the share of expenditure (s_{ni}) that country allocates to each country i, as captured in the expenditure share ($\boldsymbol{S}$) matrix.

In general, the changes in income ($\mathrm{d}\ln w_n$) and welfare ($\mathrm{d}\ln u_n$) in a given country in re-

[1] In contrast to the full non-linear model solution in equations (6) and (7), the linearization in equations (8) and (9) is based on a first-order approximation. We report quantitative results based on the full non-linear model solution below. But Kleinman et al. (2024) show that the first-order general equilibrium effects provide a good approximation to the non-linear model solution, even for relatively large shocks.

sponse to a productivity shock in another country can be either positive (friends) or negative (enemies), depending on the geography of the trade network, as summarized in the expenditure share ($\boldsymbol{S}$) and income share matrices ($\boldsymbol{T}$), and captured by the market size, cross-substitution and cost of living effects.

2.3.2 Trade Integration

We next totally differentiate the income accounting relationship (6) and welfare (7), holding constant population (ℓ_n) and the expenditure-income ratio (e_n), but allowing both productivity (z_n) in each country and bilateral trade costs (τ_{ni}) for each importer-exporter pair to change. We obtain the following generalization of the matrix representation above, incorporating the impact of changes in bilateral trade costs:

$$\mathrm{d}\ln \mathbf{w} = \mathbf{T}\,\mathrm{d}\ln \mathbf{w} + \theta\left[\mathbf{M}\left(\mathrm{d}\ln \mathbf{w} - \mathrm{d}\ln \mathbf{z}\right) + \mathbf{T}\,\mathrm{d}\ln \tau^{\mathbf{in}} - \mathrm{d}\ln \tau^{\mathbf{out}}\right], \tag{10}$$

$$\mathrm{d}\ln \mathbf{u} = \mathrm{d}\ln \mathbf{w} - \mathbf{S}\left(\mathrm{d}\ln \mathbf{w} - \mathrm{d}\ln \mathbf{z}\right) - \mathrm{d}\ln \tau^{\mathbf{in}}, \tag{11}$$

where the expenditure share ($\mathbf{S}$) and income share ($\mathbf{T}$) are defined in the same way above, and we have defined measures of inward ($\tau_n^{\mathbf{in}}$) and outward trade costs ($\tau_i^{\mathbf{out}}$), which are weighted averages of the changes in bilateral trade costs for each importer-exporter pair:

$$\mathrm{d}\ln \tau_n^{\mathbf{in}} \equiv \sum_i s_{ni}\,\mathrm{d}\ln \tau_{ni}, \tag{12}$$

$$\mathrm{d}\ln \tau_i^{\mathbf{out}} \equiv \sum_n t_{in}\,\mathrm{d}\ln \tau_{ni}, \tag{13}$$

and we report the derivations in Online Appendix B. Therefore, changes in bilateral trade costs again affect country income and welfare through market-size, cross-substitution and cost of living effects, where the changes in bilateral trade costs for each importer-exporter pair are weighted by the importance of that importer-exporter pairs in terms of expenditure shares (s_{ni}) and income shares (t_{in}).

3 Data and Parameterization

We implement our methodology using data on bilateral trade, gross domestic product (GDP) and population from 1960-2020 from the CEPII Gravity Database (Conte et al. 2022). Of the different bilateral trade variables (x_{nit}) reported, we use the series from the Direction of Trade Statistics (DOTS) of the International Monetary Fund (IMF), which ensures wide country and time coverage. We restrict attention to the years from 1960 to 2020, since country coverage is substantially more incomplete before 1960, and the data for some countries are missing after 2020. Bilateral trade is measured in current prices and thousands of US dollars at market exchange rates.

We use the GDP series (q_{nt}) that originates from the World Development Indictors (WDI) of the World Bank, supplemented with data from Barbieri (2005). GDP is again measured in current prices and thousands of US dollars at market exchange rates. We also use the population series (ℓ_{nt}) that originates from the WDI, supplemented with data from Maddison Project Database (2020). Population is measured in thousands of people.

We construct the ratio of expenditure to income for each country by combining our bilateral trade and GDP data. We measure the trade deficit as total imports minus total exports: $d_{nt} = \sum_{n=1}^{N} x_{nit} - \sum_{i=1}^{N} x_{nit}$. This trade deficit is measured in gross terms, whereas GDP is measured as value added. Therefore, to construct a comparable measure of gross income, we multiply GDP by the average ratio of gross output to value added of 2.2. Finally, we compute the ratio of expenditure to income as: $e_{nt} = 1 + (d_{nt}/ (2.2 \times q_{nt}))$.

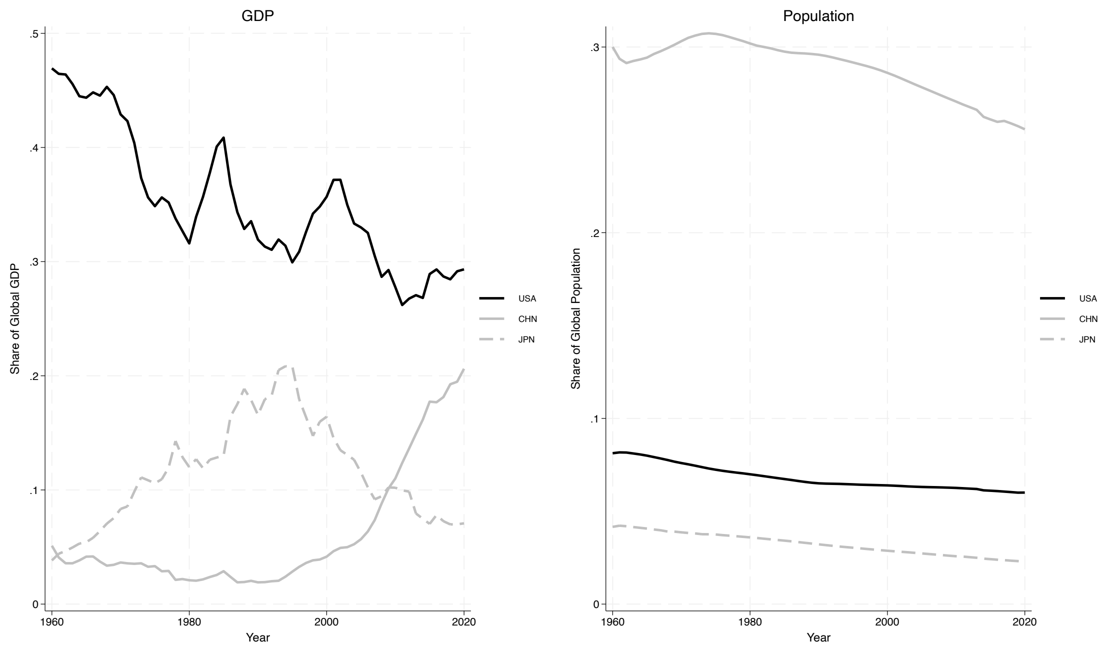
We drop small countries with a population of less than one million from our sample, in order to abstract from small sample variation in patterns of bilateral trade. We focus on a balanced panel of 75 countries for which GDP and population data are available in each year and positive values of total imports and total exports are observed in each year. We measure global GDP and population as the sum of the GDP and population of all countries included in our sample.

The class of constant elasticity trade models is indexed by a single parameter: the elasticity of trade with respect to trade costs (θ). We choose a central value for this parameter from the existing empirical literature of $\theta = 4$, which is the value estimated by Simonovska and Waugh (2014), and is close to the value of 5 used in the handbook survey by Costinot and Rodríguez-Clare (2014). We find a similar pattern of results throughout the range of empirically plausible values for this parameter from 2 to 12 in Eaton and Kortum (2002).

In Figure 1, we display the shares of the United States, China and Japan in global GDP (left panel) and population (right panel) from 1960-2020. We find a secular decline in the GDP share of the United States over time, which is particularly strong during the 1960s and 1970s. This secular decline is consistent with conditional income convergence. At the beginning of our sample period, this income convergence was in part driven by the continued recovery of Western European countries and Japan from the destruction of the Second World War. Later in our sample period, this income convergence was primarily driven by rapid economic growth in China and other emerging markets.

In the first three decades of our sample period, Japan accounts for a rising share of global GDP, reflecting its rapid economic growth after the end of the Second World War. In contrast, following the asset price collapse beginning in 1990 and subsequent slow economic growth, Japan's GDP share begins to decline, such that it is only marginally higher at the end of our sample period than it was at the beginning. In the opening two decades of our sample period, China's share of global GDP is on a gradual downward trend. Following its liberalization reforms of 1978, we observe an acceleration in its rate of economic growth and a sharp rise in its GDP share. By the end of our sample period, China remains around 10 percentage points smaller as a share of global GDP than the United States at market exchange rates.

Figure 1: Shares of Global GDP and Population



Note: shares of each country in global gross domestic product (GDP) and population; global GDP and population are defined as the sum of the GDP and population of the countries included in our sample.

Comparing the two panels of the figure, the changes in population shares of all three countries are substantially smaller than those in their GDP shares. Both Japan and the United States experience a gradual decline in their share of global population, driven by a demographic transition and rapid population growth in emerging markets. This population decline moderates for the United States after 1990, in part because of immigration. In the opening two decades of our sample period, China's population share is relatively flat, before declining from the 1970s onwards. China's much larger population share than GDP share highlights that its GDP per capita remains substantially below that of the United States throughout our sample period.

4 Model Inversion

We observe GDPs (q_{it}), population (ℓ_{it}), bilateral trade with foreign countries (x_{nit} for $n \neq i$), and compute the ratio of expenditure to income (e_{it}). We normalize the total world population equal to one in each year, such that we solve the model using population shares. This normalization is without loss of generality, because population is exogenous, and this choice of units is absorbed into the common level of productivity across all countries. We choose world GDP as our numeraire ($\sum_{n=1}^{N} q_{nt} = 1$). In our model of equipped labor, the wage is equal to income per capita. Therefore, we recover wages (w_{it}) from observed GDP (q_{it}) and population (ℓ_{it}): $w_{it} = q_{it}/\ell_{it}$.

We assume that population (ℓ_{it}) and the expenditure-income ratio (e_{it}) are exogenous. We treat GDP (and hence wages) and bilateral trade as endogenous. We now show how to invert the equilibrium conditions of the model to recover unique values for domestic trade (x_{nnt}), productivity (z_{it}) and bilateral trade costs (τ_{nit}) from the observed data (up to normalizations). Therefore, this model inversion recovers the unique values that productivities and bilateral trade costs must take in order for the observed data to be consistent with an equilibrium of the model (up to normalizations).

4.1 Domestic Trade and Wages

We solve for domestic trade (the diagonal of the expenditure share matrix $\boldsymbol{S_t}$) using the equality between country income and expenditure on the goods produced by a country in equation (6):

$$\boldsymbol{q_t} = \boldsymbol{S_t'} Diag\left(\boldsymbol{e}_t\right) \boldsymbol{q_t}. \tag{14}$$

Note that expenditure shares are defined as $s_{nit} = x_{nit} / \sum_{h=1}^{N} x_{nht}$ and we observe x_{nit} for $n \neq i$. Therefore, equation (14) provides a system of N equations in each year t that determines the N unobserved values of domestic expenditures (x_{nnt}). From these solutions for domestic expenditures, we recover the full matrix of bilateral expenditure shares (s_{nit}) between all exporter-importer pairs (including $n = i$).

4.2 Bilateral Trade Frictions

We recover bilateral trade frictions using the gravity equation relationship (5) for bilateral expenditure shares (s_{nit}). From the equilibrium pricing rule (3), we can re-write this gravity equation relationship in the following form:

$$s_{nit} = \exp\left(\eta_{it} + \mu_{nt}\right) + u_{nit} \tag{15}$$

where $\eta_{it} = \log\left(z_{it}^{\theta}\right)$ is an exporter-year fixed effect; $\mu_{nt} = \log\left(P_{nt}^{\theta}\right)$ is an importer-year fixed effect; we absorb the regression constant into these fixed effects; and u_{nit} is a regression error that includes bilateral trade frictions ($\tau_{nit}^{-\theta}$).

We estimate this gravity equation (15) for each year separately using the Poisson Pseudo Maximum Likelihood estimator (PPML) following Santos Silva and Tenreyro (2006) and Head and Mayer (2014). An advantage of this estimator is that it allows for both zero bilateral trade flows and heteroskedasticity. Instead of including observable proxies for bilateral trade frictions (such as geographical distance) in equation (15), we absorb all bilateral trade frictions into the regression error. Any exporter component of trade frictions that is common across all importers is captured in the exporter-year fixed effect. Any importer component of trade frictions that is common across all exporters is captured in the importer-year fixed effect.

Using the estimated exporter-year and importer-year fixed effects and observed expenditure shares, we compute an inverse measure of bilateral trade frictions as follows:

$$\tau_{nit}^{-\theta} = \frac{s_{nit}}{\exp\left(\eta_{it} + \mu_{nt}\right)}. \tag{16}$$

We impose our normalization that domestic trade frictions are one ($\tau_{nnt} = 1$) by dividing importer n's inverse measure of trade frictions with each exporter i ($\tau_{nit}^{-\theta}$) by its inverse measure of domestic trade frictions with itself ($\tau_{nnt}^{-\theta}$). We thus obtain our gravity openness measure (GRO_{nit}) for importer n and exporter i in each year t:

$$GRO_{nit} = \left(\frac{\tau_{nit}}{\tau_{nnt}}\right)^{-\theta} = \tau_{nit}^{-\theta} = \frac{s_{nit}/\exp\left(\eta_{it}\right)}{s_{nnt}/\exp\left(\eta_{nt}\right)}. \tag{17}$$

Higher values of gravity openness GRO_{nit} corresponds to *lower* foreign trade frictions relative to domestic trade frictions. In the limiting case of infinite bilateral trade costs ($\tau_{nit} \to \infty$), bilateral trade equals zero, and gravity trade openness takes the value zero ($GRO_{nit} = 0$). In the opposite limiting case of no bilateral trade frictions ($\tau_{nit} = 1$), relative expenditure shares depend solely on relative exporter size (as captured by the relative exporter-year fixed effects), and gravity openness takes the value one ($GRO_{nit} = 1$). Our normalization of domestic trade frictions to one ($\tau_{nnt} = 1$) is necessary to separately identify bilateral trade frictions from productivity, because otherwise a reduction in bilateral trade frictions with all countries (including the own country) is isomorphic to an increase in productivity.

Intuitively, importer n has high trade openness with exporter i in equation (17) when its expenditure share with that exporter is high relative to its domestic expenditure shares compared to what would be predicted based on the relative size of the two countries (as captured by the exporter-year fixed effects). While we interpret gravity openness measures as reflecting bilateral trade frictions, it includes anything that shifts bilateral expenditure shares that is not captured by the importer-year and exporter-year fixed effects, including for example changes in countries bilateral tastes for one another's goods.

This gravity openness measure in equation (17) has a number of advantages. First, it is invariant to the choice of units in which to measure the fixed effects, because the importer-year fixed effect ($\exp\left(\mu_{nt}\right)$) is differenced out, and the choice of units for the exporter-year fixed effect ($\exp\left(\eta_{it}\right)$) cancels from the numerator and denominator in equation (17). Second, gravity openness is defined to include the trade elasticity, which ensures that it is invariant to the assumed value of this trade elasticity (θ). Instead, gravity openness is pinned down by the observed expenditure shares (s_{nit}) and the exporter-year fixed effects (η_{it}) alone. Third, gravity openness allows for asymmetric trade frictions, such that $(\tau_{nit}/\tau_{nnt})^{-\theta} \neq (\tau_{int}/\tau_{iit})^{-\theta}$.

As a check on this gravity openness measure, we also compute the Head-Ries openness measure (HRO_{nit}) from Head and Ries (2001), which under the assumption of symmetric trade frictions ($\tau_{nit} = \tau_{int}$), and the normalization of domestic trade frictions to one ($\tau_{nnt} = \tau_{iit} = 1$), can be used to recover bilateral trade frictions:

$$HRO_{nit} = \left(\frac{\tau_{nit}}{\tau_{nnt}} \frac{\tau_{int}}{\tau_{iit}} \right)^{-\frac{\theta}{2}} = (\tau_{nit})^{-\theta} = \left(\frac{s_{nit}}{s_{nnt}} \frac{s_{int}}{s_{iit}} \right)^{\frac{1}{2}}. \tag{18}$$

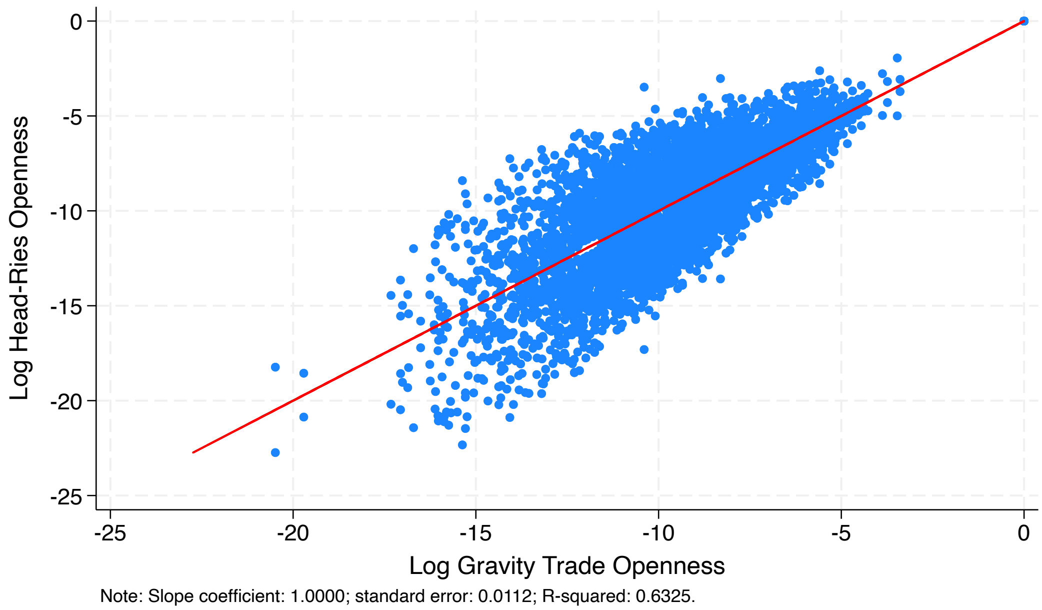
As for gravity openness above, higher values of Head-Ries openness correspond to *lower* foreign trade frictions relative to domestic trade frictions. In the limiting case of infinite trade costs, Head-Ries openness is equal to zero. In contrast, in the opposite limiting case of free trade, Head-Ries openness is equal to one. Intuitively, countries n and i have high trade openness with one another when the product of their expenditure shares with one another is high relative to the product of their domestic expenditure shares. While we again interpret Head-Ries openness as capturing bilateral trade frictions, it also captures bilateral variation in tastes between pairs of exporting and importing countries.

In Figure 2, we display log Head-Ries openness against our log gravity openness for the year 2000. We find a strong correlation between the two measures, which is consistent with both capturing underlying bilateral trade frictions between countries. Taking the geometric mean of gravity openness (17), we find that the two measures are related as follows:

$$HRO_{nit} = \left(\frac{\tau_{nit}}{\tau_{nnt}} \frac{\tau_{int}}{\tau_{iit}} \right)^{-\frac{\theta}{2}} = (GRO_{nit} GRO_{int})^{\frac{1}{2}} = \left(\frac{s_{nit}}{s_{nnt}} \frac{s_{int}}{s_{iit}} \right)^{\frac{1}{2}}. \tag{19}$$

When we regress log gravity openness on log Head-Ries openness, we find an elasticity of one. The regression R-squared is around 0.65, which is consistent with the idea that bilateral trade costs are not perfectly symmetric between countries. Furthermore, there is evidence of heteroskedasticity, with a greater discrepancy between the two measures at low values of trade openness. Therefore, although these two measures of bilateral trade openness are strongly correlated with one another, there is additional information in allowing for asymmetric bilateral trade costs. These results are consistent with the evidence in Waugh (2010), which finds substantial asymmetries in bilateral trade costs for country pairs, and shows that they are consequential for real income and total factor productivity (TFP) across countries.

Figure 2: Head-Ries and Gravity Openness in 2000

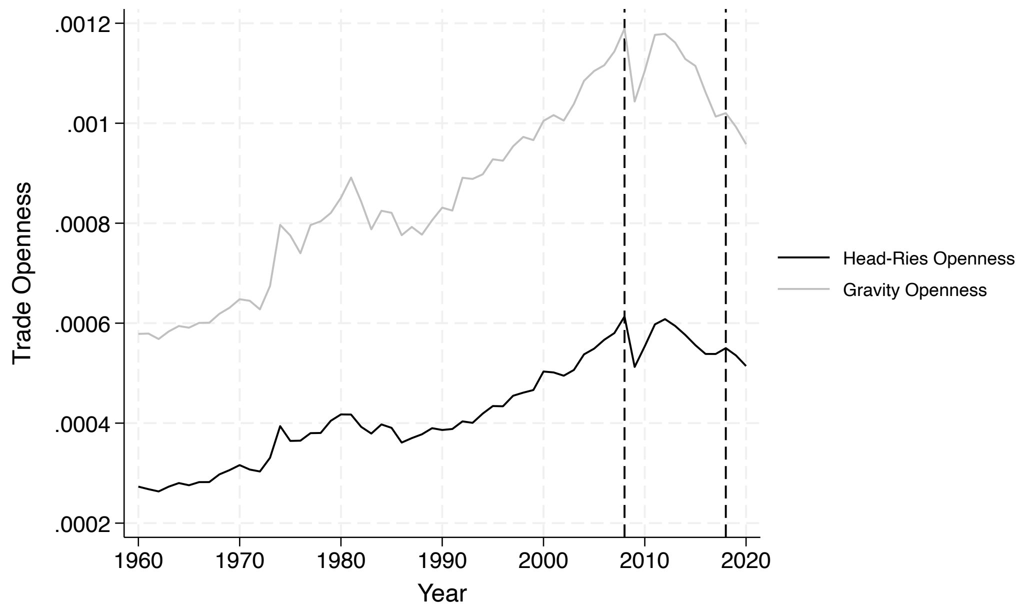


Note: Head-Ries openness defined as $HRO_{nit} \equiv \left(\left(s_{nit} / s_{nnt} \right) \left(s_{int} / s_{iit} \right) \right)^{1/2}$, where s_{nit} is the expenditure share of importer n on exporter i; gravity openness defined as $GRO_{nit} \equiv \left(\tau_{nit} / \tau_{nnt} \right)^{-\theta} = \frac{s_{nit} / \exp(\eta_{it})}{s_{nnt} / \exp(\eta_{nt})}$, where η_{it} are the exporter-year fixed effects from PPML gravity equation estimation; figure shows the logs of both variables; higher values of both openness measures correspond to *lower* foreign trade frictions relative to domestic trade frictions (lower τ_{nit}/τ_{nnt}); blue dots correspond to importer-exporter pairs in 2000; red line shows the linear regression fit.

In Figure 3, we plot the unweighted average of both openness measures across all bilateral exporter-importer pairs in each year. We find that Head-Ries openness is less than gravity openness in each year, which is consistent with the fact that the Head-Ries index for each country pair is the geometric mean of gravity openness in each direction (equation (19)), and the geometric mean is in general smaller than the arithmetic mean. We find an increase in globalization from 1960-2008, which accelerates during the period from the late 1980s to the Great Financial Crisis (GFC) in 2008, sometimes described as a period of "hyper globalization" (e.g., Antràs 2021). This acceleration is more evident using Gravity Openness than using Head-Ries Openness. This acceleration is also consistent with findings using simpler measures of globalization not directly derived from a gravity equation, such as the ratio of trade to GDP.

Following the GFC in 2008, we observe a slowdown in globalization ("snowbalization"), and even some evidence of a reverse in globalization ("deglobalization"). This decline in globalization after 2008, and a further decline after the beginning of the US-China Trade War in 2018 is again more evident using Gravity Openness than using Head-Ries Openness. We find that the overall level of trade openness is higher for our Gravity Openness measure. This pattern is consistent with the idea that bilateral pairs with disproportionately high trade volumes and low trade frictions in one direction may have lower trade volumes and higher trade frictions in the other direction, such that averaging using the geometric mean in Head-Ries Openness reduces measured trade openness. Nevertheless, both openness measures are substantially below one, which reflects the fact that international trade is a relatively small share of gross output, particularly for large countries such as the United States.

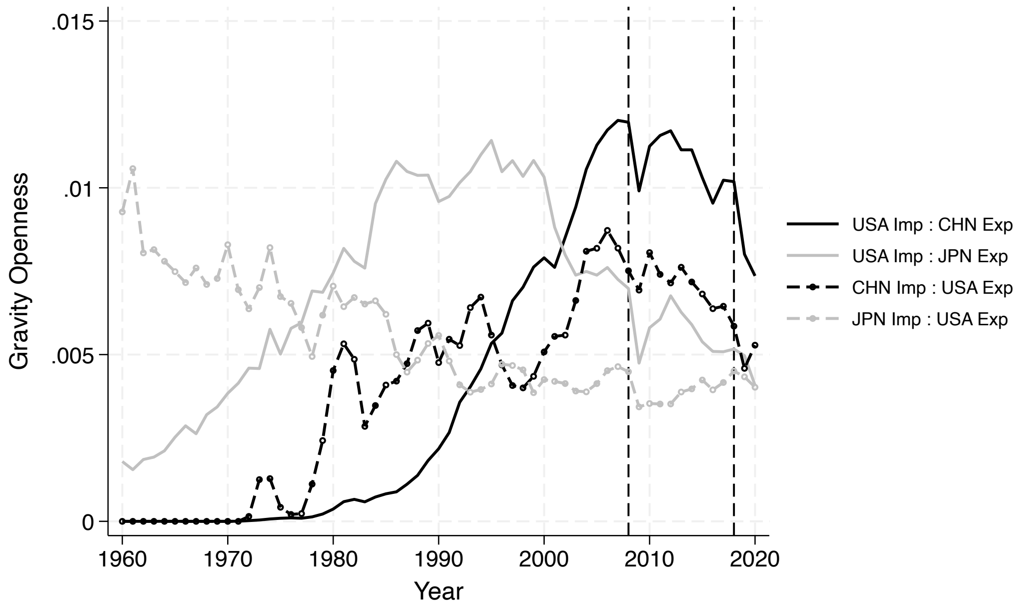
Figure 3: Global Trade Openness Over Time



Note: Unweighted averages of Head-Ries and Gravity openness across all exporter-importer pairs in each year (excluding each country's openness with itself); Head-Ries openness defined as $HRO_{nit} \equiv ((s_{nit}/s_{nnt})(s_{int}/s_{iit}))^{1/2}$, where s_{nit} is the expenditure share of importer n on exporter i; gravity openness defined as $GRO_{nit} \equiv (\tau_{nit}/\tau_{nnt})^{-\theta} = \frac{s_{nit}/\exp(\eta_{it})}{s_{nit}/\exp(\eta_{nt})}$, where η_{it} are the exporter-year fixed effects from PPML gravity equation estimation; figure shows levels (and not logs); higher values of both openness measures correspond to *lower* foreign trade frictions relative to domestic trade frictions (lower τ_{nit}/τ_{nnt}); vertical lines show 2008 (Global Financial Crisis) and 2018 (beginning of US-China Trade War).

In Figure 4, we display our Gravity Openness measure for the bilateral trade of the United States with China and Japan (in both directions). At the beginning of our sample period, the United States and China were largely closed to trade with one another. Following its liberalization reforms of 1978, China initially has higher openness with the United States than the United States has with China, before this pattern is reversed from the mid 1990s onwards. Japan's openness towards the United States is initially higher than the United States's openness to Japan, before declining gradually over time. The openness of the United States to Japan peaks in the late 1980s and early 1990s during the years of the most intense debate in the United States about competition from Japan, before declining from the late 1990s onwards.

Figure 4: Gravity Openness (USA-CHN and USA-JPN) Over Time



Note: gravity openness defined as $GRO_{nit} \equiv (\tau_{nit}/\tau_{nnt})^{-\theta} = \frac{s_{nit}/\exp(\eta_{it})}{s_{nit}/\exp(\eta_{nt})}$, where s_{nit} is the expenditure share of importer n on exporter i, and η_{it} are the exporter-year fixed effects from PPML gravity equation estimation; figure shows levels (and not logs); higher values of openness correspond to *lower* foreign trade frictions relative to domestic trade frictions (lower τ_{ni}/τ_{nn}); vertical lines show 2008 (Global Financial Crisis) and 2018 (beginning of US-China Trade War).

4.3 Productivities

We recover country productivities from the equality between country income and expenditure on the goods produced by that country in equation (6), which can be written as follows:

$$w_{it}\ell_{it} = \sum_{n=1}^{N} \frac{\tau_{nit}^{-\theta}\left(w_{it}/z_{it}\right)^{-\theta}}{\sum_{h=1}^{N}\tau_{nht}^{-\theta}\left(w_{ht}/z_{ht}\right)^{-\theta}} e_{nt}w_{nt}\ell_{nt}. \tag{20}$$

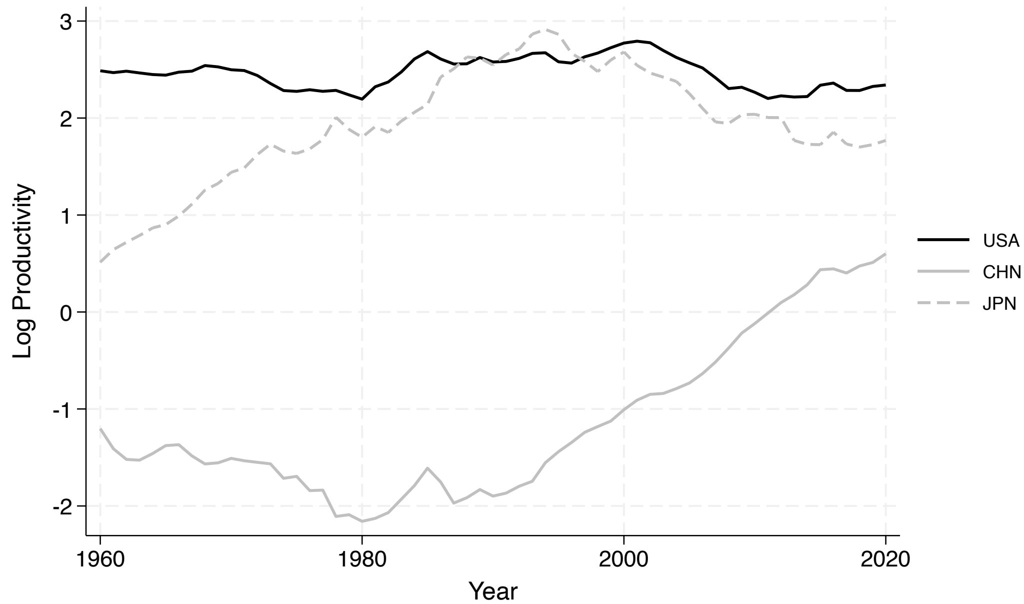
where population (ℓ_{nt}) and wages (w_{nt}) are observed; we computed the ratio of expenditure to income (e_{nt}) from observed data; and we solved for inverse bilateral trade frictions ($\tau_{nit}^{-\theta}$) from our PPML gravity equation estimation above.

Given our assumed value for the trade elasticity (θ), the income accounting relationship (20) provides a system of N equations that can be solved for unique values of the N unobserved productivities (z_{nt}), up to a normalization or choice of units for productivity. A normalization is required, because the terms in expenditure shares in equation (20) are homogenous of degree zero, and hence productivity only can be determined up to a multiplicative constant. We choose the normalization that the geometric mean of productivities across all countries in our sample is equal to one: $\left(\prod_{n=1}^{N} z_{nt}\right)^{\frac{1}{N}} = 1$. Our model inversion thus allows us to measure changes in relative levels of productivity across countries over time and quantify their impact on GDP shares and welfare. We abstract from common increases in global productivity that raise the welfare of all countries proportionately and leave GDP shares unchanged.

Intuitively, if a country has a high income ($w_{nt}\ell_{nt}$) relative to other nations on the left-hand side of equation (20), given its wage costs (w_{nt}) and bilateral trade frictions ($\tau_{nit}^{-\theta}$) to markets on the right-hand side of this relationship, the model implies that this high relative income must be explained by its high relative productivity. Whereas our measures of bilateral costs ($\tau_{nit}^{-\theta}$) above could be recovered without making an assumption about the trade elasticity, we are now required to take a stand on this parameter in order to measure productivity, because the trade elasticity enters as the exponent on wages in equation (20).

In Figure 5, we display the productivities from our model inversion for the United States, China and Japan over time. The United States has by far the highest initial level of productivity at the beginning of our sample period. Productivity in Japan converges rapidly towards that in the United States in the opening decades of our sample, before briefly overtaking U.S. levels in the early 1990s, and then falling below U.S. levels by the end of our sample period. China's productivity begins substantially below levels in both countries and is only on a downward trend during the 1960s and 1970s. Following China's domestic reforms of 1978, we find a marked acceleration in its rate of productivity growth, although its level of productivity remains substantially below that in the United States at the end of our sample period.

Figure 5: Country Productivities



Note: log country productivities from model inversion in each year; productivities recovered from the general equilibrium equality between country income and expenditure on the goods produced by a country; productivity model inversion uses bilateral trade frictions from PPML gravity estimation; domestic trade frictions normalized to one ($\tau_{nnt} = 1$); geometric mean of country productivities normalized to one in each year ($\left(\prod_{n=1}^{N} z_{nt}\right)^{\frac{1}{N}} = 1$).

5 Counterfactuals

We now use our solutions for productivities $\{z_{nt}\}$ and bilateral trade frictions $\{\tau_{nit}^{-\theta}\}$ from our model inversion to provide evidence on the determinants of countries' GDP shares and welfare over time. The general equilibrium is referenced by the vector of endogenous wages $\{w_{nt}\}$, from which all other endogenous variables can be determined, including expenditure shares $\{s_{nit}\}$, GDP $\{q_{nt}\}$, price indexes $\{\mathcal{P}_{nt}\}$ and welfare $\{\mathcal{U}_{nt}\}$. Endogenous wages are in turn determined by the four exogenous primitives of productivities $\{z_{nt}\}$, bilateral trade costs $\{\tau_{nit}\}$, population shares $\{\ell_{nt}\}$, and expenditure-income ratios $\{e_{nt}\}$.

5.1 Counterfactual Solutions

We solve for a counterfactual equilibrium using the general equilibrium system of equations that equates country income with expenditure on the goods produced by a country:

$$\widetilde{w}_{it}\widetilde{\ell}_{it} = \sum_{n=1}^{N} \frac{\widetilde{\tau}_{nit}^{-\theta} \left(\widetilde{w}_{it}/\widetilde{z}_{it}\right)^{-\theta}}{\sum_{h=1}^{N} \widetilde{\tau}_{nht}^{-\theta} \left(\widetilde{w}_{ht}/\widetilde{z}_{ht}\right)^{-\theta}} \widetilde{e}_{nt}\widetilde{w}_{nt}\widetilde{\ell}_{nt}, \tag{21}$$

where a tilde above a variable denotes a counterfactual value.

Our model inversion recovers unique values for productivities and bilateral trade frictions for which the observed data are an equilibrium of the model (up to normalizations). Therefore, if we feed in these model-inverted values for productivities and bilateral trade frictions in each year $\{\widetilde{\tau}_{nit}^{-\theta} = \tau_{nit}^{-\theta}, \widetilde{z}_{it} = z_{it}\}$, together with the observed population shares and expenditure-income ratios in each year $\{\widetilde{\ell}_{nt} = \ell_{nt}, \widetilde{e}_{nt} = e_{nt}\}$, and solve for a counterfactual equilibrium, the model's counterfactual predictions for wages and all the other endogenous variables of the model exactly replicate the observed values of these endogenous variables in the data in each year $\{\widetilde{w}_{nt} = w_{nt}\}$.

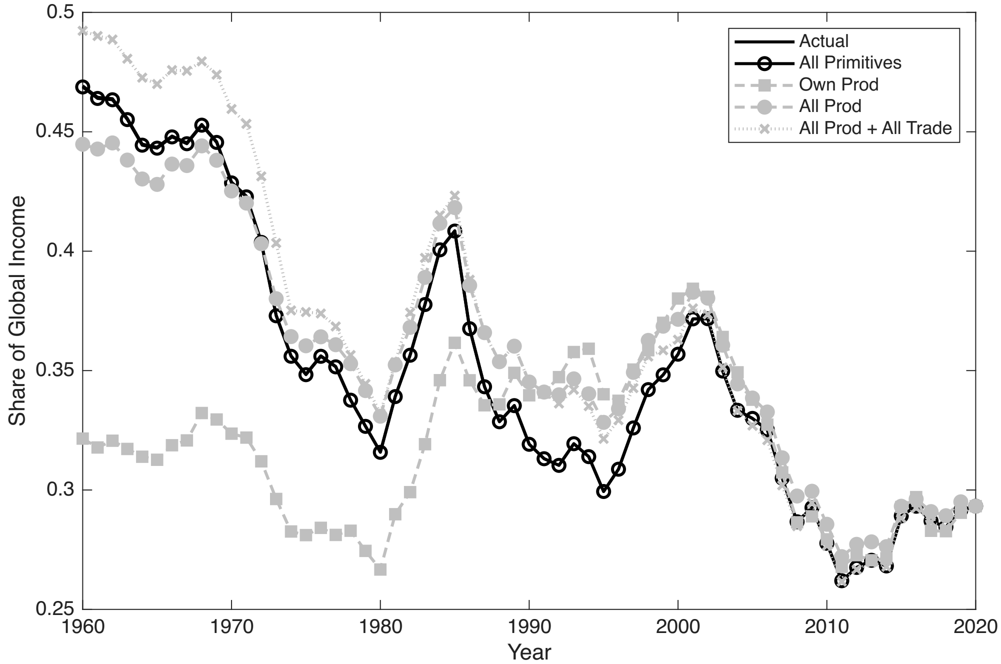
To explore the role of productivities and bilateral trade costs relative to other model primitives, we feed in the model-inverted values for productivities and bilateral trade frictions in each year $\{\widetilde{\tau}_{nit}^{-\theta} = \tau_{nit}^{-\theta}, \widetilde{z}_{it} = z_{it}\}$, but hold the other model primitives constant at their values at the end of our sample period ($\widetilde{\ell}_{nt} = \ell_{nT}, \widetilde{e}_{nt} = e_{nT}$), and solve for a counterfactual predictions. In this case, the model's counterfactual predictions need not equal the observed values of the endogenous variables in the data in each year, and the gap between the model's counterfactual predictions and the observed data tells us about the importance of productivities and bilateral trade costs relative to other model primitives.

5.2 Productivity, Trade Costs and U.S. Relative Income

In Figure 6, we examine the role of domestic productivity, foreign productivity and bilateral trade frictions in shaping the evolution of the U.S. share of global GDP over time. The black-solid line with no markers shows the actual U.S. GDP share in each year. The black-solid line with open-circle markers shows the model's counterfactual predictions if we allow all model primitives to change over time, which exactly replicates the observed data, as discussed above.

The gray-dashed line with filled-square markers shows the model's counterfactual predictions if we allow U.S. productivity to change over time, but hold productivity in all other countries and all other model primitives constant at their values at the end of our sample period. The gray-dashed line with filled-circle markers shows the model's counterfactual predictions if we allow all country productivities to change over time, but hold all other model primitives constant at their values at the end of our sample period. The gray-dotted line with cross markers shows the model's counterfactual predictions if we allow all country productivities and all bilateral trade frictions to change over time, but hold population shares and expenditure-income ratios constant at their values at the end of our sample period.

Figure 6: Productivity Growth, Globalization and the US Share of Global Income



Note: Black-solid line with no markers shows actual values; black-solid line with open-circle markers shows counterfactual values allowing all exogenous primitives to change over time (productivities, bilateral trade costs, population shares, and expenditure-income ratios), gray-dashed line with filled-square markers shows counterfactual values allowing U.S. productivity to change over time, but holding all other exogenous primitives constant at their values at the end of our sample period; gray-dashed line with filled-circle markers shows counterfactual values if we allow all country productivities to change over time, but hold all other model primitives constant at their values at the end of our sample period; gray-dotted line with cross markers shows counterfactual values if we allow all country productivities and all bilateral trade frictions to change over time, but hold population shares and expenditure-income ratios constant at their values at the end of our sample period.

We find a pattern of results consistent with Paul Krugman's aphorism that "Productivity isn't everything, but in the long run it is almost everything" (Krugman 1994a). Even when we only allow U.S. productivity to change over time, the model's counterfactual predictions closely approximate the observed data back the late 1980s (gray-dashed line with filled-square markers). Once we allow all countries productivities to change over time (gray-dashed line with filled circle markers), we find that the model is able to closely approximate the observed data throughout the entire sample period. When we introduce variation in all countries' productivities and bilateral trade costs (gray-dotted line with cross markers), the model's counterfactual predictions remain close to the observed data, with the model if anything predicting a higher U.S. GDP share than observed in the data at the beginning of our sample period. The gap between the model's predictions and the observed data in this final counterfactual reflects the impact of changes in countries' population shares and expenditure-income ratios over time.

Therefore, a first key insight form our quantitative analysis is that the decline in the U.S. share of GDP over our sample period is largely driven by slower productivity growth in the United States than other countries, in part because of productivity catchup in Western Europe and Japan in the opening decades of our sample period, and in China and other emerging economies in the closing decades of our sample period.

5.3 Globalization, GDP shares and Welfare

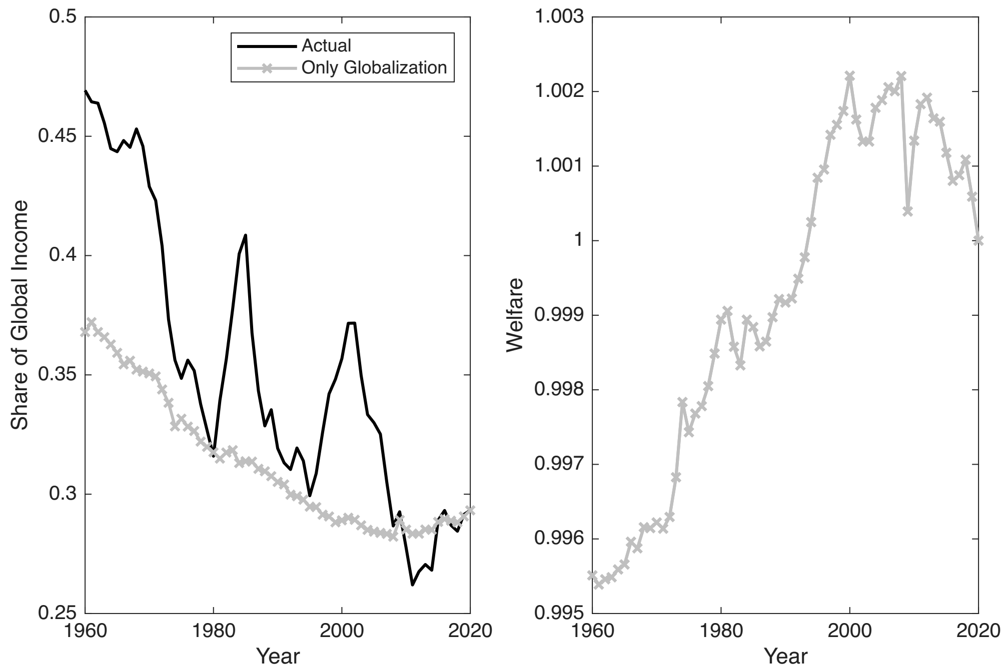
In Figure 7, we examine the impact of reductions in international trade frictions alone on the share of the United States in global GDP (left panel) and its welfare (right panel).

The figure has a similar structure to the previous figure. The black-solid line with no markers in the left panel again shows the actual U.S. GDP share. The gray-solid line with cross markers in this panel shows the model's counterfactual predictions if we allow bilateral trade frictions to change over time, but hold all other model primitives constant at their values at the end of our sample period. Therefore, the model's counterfactual predictions are exactly equal to the observed data in the final year of sample, but in general diverge from the observed data in other years.

In most years, the counterfactual U.S. GDP share with historical trade frictions is higher than the actual U.S. GDP share with the values of trade frictions at the end of our sample period. Therefore, the reductions in trade frictions that occurred in the decades after the Second World War reduced the share of the U.S. in global GDP, which reflects negative terms of trade effects. At the beginning of our sample period, the U.S. had relatively low bilateral trade frictions to markets compared to other countries. Over time, other countries experienced larger reductions in their bilateral trade frictions to markets than the U.S., which reduced their relative prices in those markets compared to the United States. In response, consumers substituted away from U.S. goods towards those of other countries, thereby bidding down wages in the United States relative to those in other countries.

Although other countries benefited more from globalization than the United States in terms of relative incomes, we nevertheless find that the United States gained in terms of welfare (right panel). Reductions in the price of other countries goods led to cross-substitution away from U.S. goods, but they also reduced consumer prices in the United States, thereby raising real income. Therefore, a second key insight from our analysis is that changes in countries' relative incomes are potentially quite misleading for welfare changes over time.

Figure 7: Globalization and the US Share of Global Income



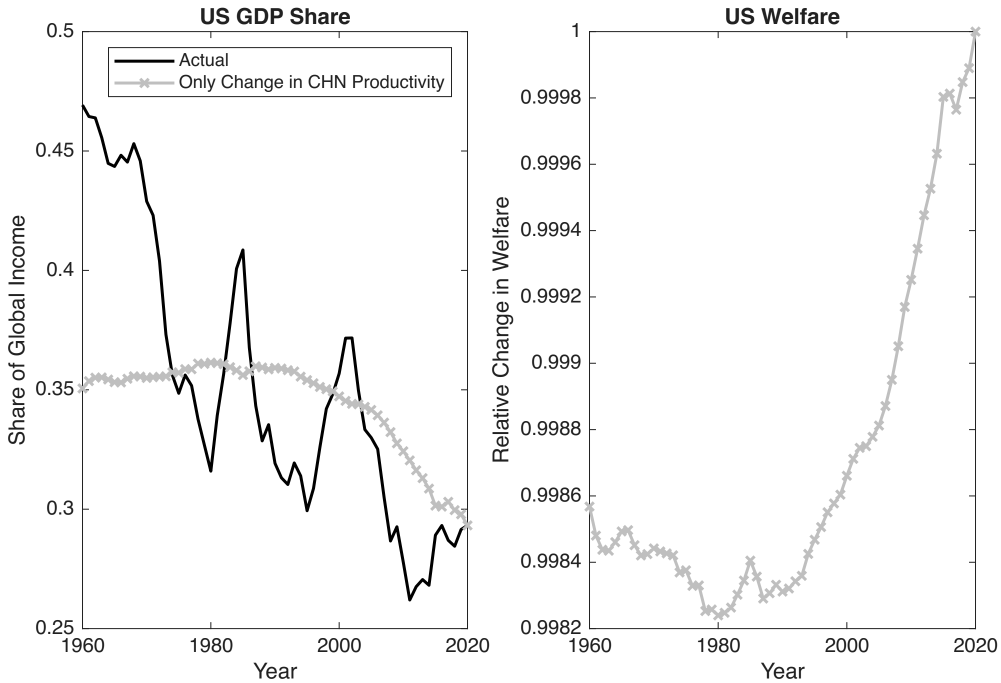
Note: left panel shows US share of global GDP ($q_n / \sum_{k=1}^{N} q_k$); right panel shows US welfare ($w_n/\mathcal{P}_n$); black-solid line shows actual values; gray-solid line with cross markers shows counterfactual predictions in which all exogenous country characteristics (population shares, proportional deficits, bilateral trade frictions and productivity) are held constant at their 2020 values, except for bilateral trade costs, which are set equal to their values from our model inversion in each year; bilateral trade frictions recovered from PPML gravity equation estimation; domestic trade frictions normalized to one.

5.4 Income and Welfare Effects of China's Emergence

In Figure 8, we examine the impact of China's productivity growth on the share of the United States in global GDP and its welfare.

The figure again has a similar structure. The black-solid line with no markers in the left panel again shows the actual U.S. GDP share. The gray-solid line with cross markers in this panel shows the model's counterfactual predictions if we allow China's productivity to change over time, but hold all other model primitives constant at their values at the end of our sample period. Therefore, the model's counterfactual predictions are exactly equal to the observed data in the final year of sample, but in general diverge from the observed data in other years.

Figure 8: Impact of Chinese Productivity Growth on US Share of Global GDP and Welfare



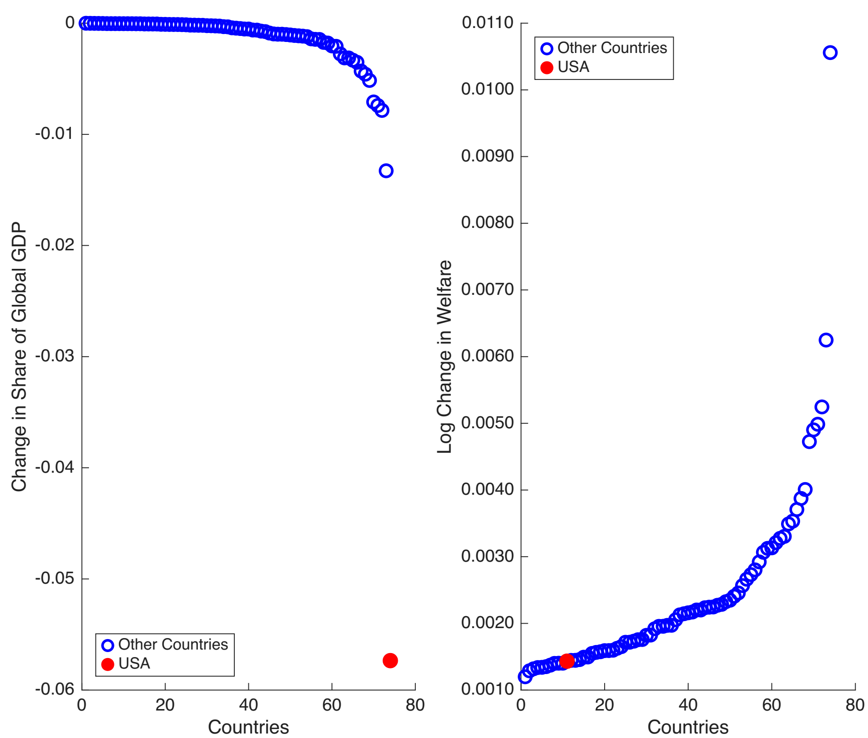
Note: left panel shows U.S. share of global GDP ($q_n / \sum_{k=1}^{N} q_k$); right panel shows U.S. welfare ($w_n / \mathcal{P}_n$); black line corresponds to data; gray line with crosses shows a model counterfactual in which all variables are held constant at their 2020 values, except for Chinese productivity which in each year equals its value from our model inversion; global GDP is the sum of the GDP of all countries included in our sample.

In the opening decades of our sample period, China's relative productivity in Figure 5 is on a gradual downward trend, but the country is largely closed to international trade. Therefore, we find little impact of changes in China's relative productivity on the U.S. GDP share in the left panel, as reflected in the relatively flat gray line. In contrast, following China's domestic liberalization in 1978, we observe a steep increase in its relative productivity in Figure 5, and an increase in its integration into international markets (as illustrated for the U.S. market in Figure 4), which leads to a decline in the U.S. GDP share in the last three decades of our sample in the left panel. While this decline in the U.S. GDP share is partly explained by cross-substitution away from U.S. goods, as the increase in China's productivity reduces the relative price of its goods in markets around the world, it mostly reflects the mechanical effect of China becoming bigger, as its productivity growth raises its own GDP, thereby increasing the denominator in the U.S. GDP share.

Although this China's rapid productivity growth from 1978 onwards reduces the U.S. GDP share in the left panel, it nevertheless increases U.S. welfare in the right panel. The increase in China's productivity not only leads to cross-substitution effects in markets around the world, but also reduces consumer prices in the United States, thereby raising real income. These findings again highlight the danger of drawing inferences about welfare from changes in the relative economic size of countries.

Although Figure 8 focuses on effects on the United States, the increase in China's productivity affects the GDP share and welfare of each country around the world. In Figure 9, we provide evidence on the heterogeneity of these effects across countries. The left panel shows the counterfactual change in each country's GDP share induced by increasing China's productivity from its 1960 to its 2020 value, holding all other model primitives constant at their 2020 values. The right panel shows the counterfactual change in each country's welfare caused by this increase in China's productivity from 1960-2020, holding all other model primitives constant at their 2020 values.

Figure 9: Impact of Chinese Productivity Growth from 1960-2020 on Countries' Shares of Global GDP and Welfare



Note: left panel shows the change in country shares of global GDP ($q_n / \sum_{k=1}^{N} q_k$) from holding all variables constant at their 2020 values, except for Chinese productivity, which is increased from its 1960 value to its 2020 value; right panel shows the log change in country welfare (w_n/P_n) from holding all variables constant at their 2020 values, except for Chinese productivity, which is increased from its 1960 value to its 2020 value; solid red circle shows the United States; blue hollow circles show all other countries.

As shown in the left panel, we find that the U.S. experiences by far the largest decline in its GDP share as a result of China's productivity growth. This pattern reflects the fact that we show the change in the GDP share (rather than the percentage change in the GDP share), and the U.S. accounts for by far the largest share of GDP at the beginning of our sample period. Therefore, even a common percentage reduction in all countries GDP shares would result a larger change in the GDP share of the United States than any other country. As shown in the right panel, we find that the U.S. experiences relative modest welfare gains as a result of China's productivity growth. This pattern is again driven by the fact that the U.S. is a large country relative to the other countries included in our sample and hence has a relatively large domestic trade share.

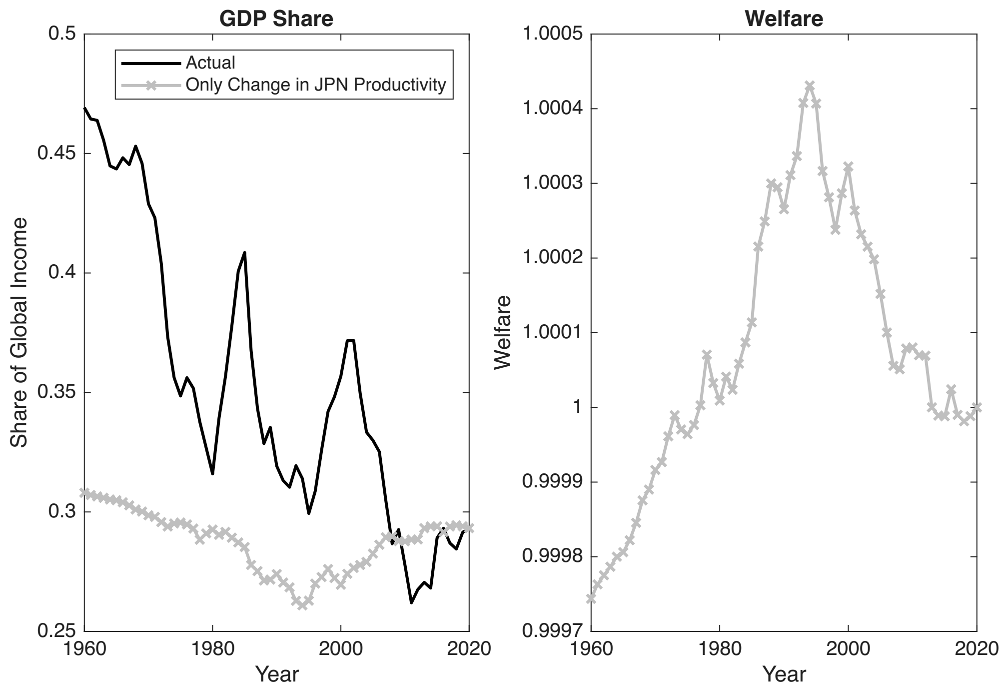
These findings reinforce the idea that the emergence of China into the global economy as a result of its rapid productivity growth naturally should be expected to lead to a decline in the relative economic size of countries, but this relative economic decline can go hand-in-hand with an increase in welfare in other countries. However, the welfare gains for other countries are relatively small, because trade accounts for a relatively small share of countries' GDP and China is only one trade partner. As a large economy, the U.S. is a country that experiences the largest percentage point change in its share of global GDP, combined with a relatively small percentage change in its welfare.

5.5 Income and Welfare Effects of Japan's Emergence

In Figure 10, we examine the impact of Japan's productivity growth on the share of the United States in global GDP and its welfare.

The figure again has a similar structure. The black-solid line with no markers in the left panel again shows the actual U.S. GDP share. The gray-solid line with cross markers in this panel shows the model's counterfactual predictions if we allow Japan's productivity to change over time, but hold all other model primitives constant at their values at the end of our sample period. Therefore, the model's counterfactual predictions are exactly equal to the observed data in the final year of sample, but in general diverge from the observed data in other years.

Figure 10: Impact of Japanese Productivity Growth on US Share of Global GDP and Welfare

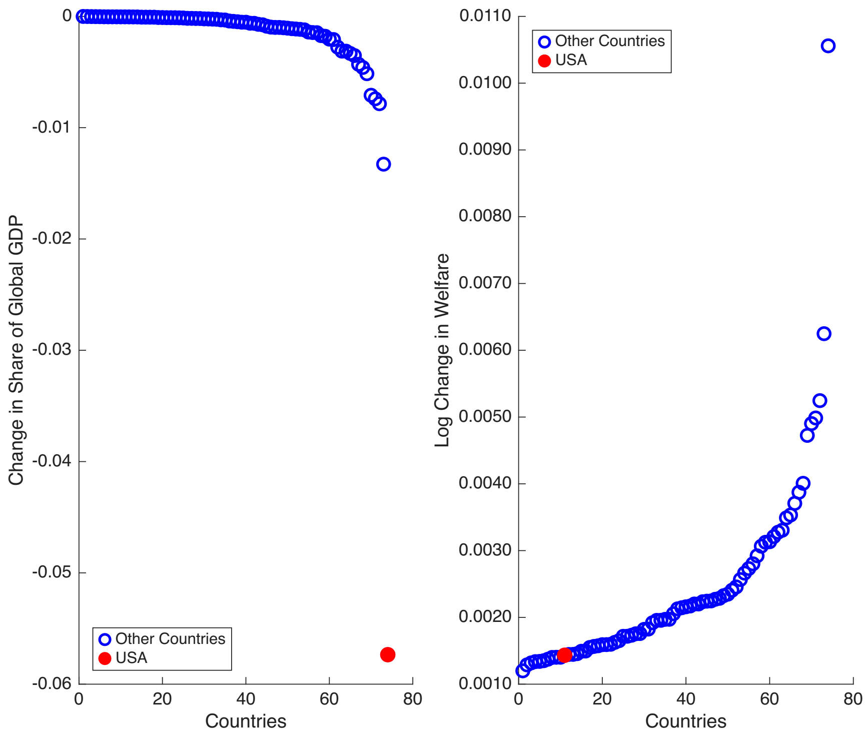


Note: left panel shows U.S. share of global GDP ($q_n / \sum_{k=1}^{N} q_k$) and right panel shows U.S. welfare (w_n/P_n); black line corresponds to data; gray line with crosses shows a model counterfactual in which all variables are held constant at their 2020 values, except for Japanese productivity which in each year equals its value from our model inversion; global GDP is the sum of the GDP of all countries included in our sample.

We find a non-monotonic relationship between changes in Japan's productivity and the US GDP share and welfare, which reflects the fact that Japan's productivity rises relative to the U.S. for the first three decades of our sample period, but then declines relative to the US for the remainder of our sample period in Figure 5. Therefore, in the first three decades of our sample period, we find the same pattern for Japan as for China in the previous section. The increase in Japan's productivity leads to a decline in the US GDP share, but a rise in its welfare. In the remaining decades of our sample, we find the mirror image of these results. The decrease in Japan's productivity leads to a rise in the US GDP share, but a decline in its welfare. Although the movements in the U.S. GDP share are partly explained by cross-substitution effects from the impact of changes in Japanese productivity on the relative price of Japanese goods, they are heavily influenced by mechanical effects from changes in the size of the Japanese economy directly affected the denominator of the U.S. GDP share.

In Figure 11, we examine the heterogeneity of these effects of changes in Japan's productivity across countries. The left panel shows the counterfactual change in each country's GDP share induced by increasing Japan's productivity from its 1960 to its 2020 value, holding all other model primitives constant at their 2020 values. The right panel shows the counterfactual change in each country's welfare caused by this increase in Japan's productivity from 1960-2020, holding all other model primitives constant at their 2020 values.

Figure 11: Impact of Japanese Productivity Growth from 1960-2020 on Countries' Shares of Global GDP and Welfare



Note: left panel shows the change in country shares of global GDP ($q_n / \sum_{k=1}^{N} q_k$) from holding all variables constant at their 2020 values, except for Japanese productivity, which is increased from its 1960 value to its 2020 value; right panel shows the log change in country welfare ($w_n/\mathcal{P}_n$) from holding all variables constant at their 2020 values, except for Japanese productivity, which is increased from its 1960 value to its 2020 value; solid red circle shows the United States; blue hollow circles show all other countries.

As for China in the previous section, we find that the U.S. experiences by far the largest decline in its GDP share as a result of Japan's productivity growth. Again, this finding is driven by the fact that this figure shows the change in share (rather than the percentage change), and the U.S. accounts for by far the largest share of GDP at the beginning of our sample period. Similarly, we find that the U.S. experiences relatively modest welfare gains as a result of Japan's productivity growth. This finding is again driven by the fact that the U.S. is a large country and hence has a relatively high domestic trade share. But the U.S. experiences relatively larger welfare gains from increases in Japan's productivity than from increases in China's productivity, compared to other countries around the world.

These findings from the emergence of Japan into the global economy reinforce our conclusions from the emergence of China. The emergence of a major new economy naturally leads to a relative decline in GDP in existing leading economies, but this relative economic decline can involve an increase in welfare. More broadly, the effects of changes in productivity in other countries on welfare in the own country are small relative to those of changes in the own country's productivity, particularly for large countries such as the United States for which trade is a relatively small share of GDP.

6 Conclusions

History provides examples of large changes in the relative economic size of nations that often bring heightened geopolitical tension. How are aggregate income and welfare in advanced countries affected by globalization and productivity growth in emerging economies? We use the class of constant elasticity trade models and data on bilateral trade, national income and population from 1960-2020 to provide quantitative evidence on these questions.

We use the structure of these models to recover measures of bilateral trade frictions and productivities for which the observed data are consistent with equilibrium. We document reductions in worldwide trade frictions over the course of our sample period as a whole ("globalization"). This globalization was particularly rapid from the late 1980s to the Great Financial Crisis of 2008 ("hyper globalization"), but moved into reverse from then onwards ("deglobalization"). We find that Japan's productivity rapidly converges towards U.S. levels during the opening decades of our sample, before falling back from 1990 onwards. Following China's domestic liberalization in 1978, we observe an acceleration in its rate of productivity growth, although it remains substantially below U.S. productivity at the end of our sample period.

Using these model-inverted measures of trade frictions and productivities, we undertake counterfactuals to assess the contributions of domestic productivity growth, foreign productivity growth and globalization to changes in countries' shares of global GDP and welfare. We find that globalization reduced the share of the United States in global GDP, as other countries experienced larger reductions in their trade friction to markets around the world, which led consumers to substitute away from the goods produced by the United States. Nevertheless, this globalization raised aggregate welfare in the United States, because the reduction in the price of other countries' goods lowered the cost of living in the United States.

We find that rapid productivity growth in Japan (towards the beginning of our sample period) and China (towards the end of our sample period) contributed towards this reduction in the share of the United States in global GDP. While this relative economic decline is partly explained by resulting cross-substitution away from U.S. goods in markets around the world, it mostly reflects the compositional effect from these countries becoming larger, thereby increasing the denominator in the U.S. GDP share. Nevertheless, we find that productivity growth in these countries raised aggregate U.S. welfare, through reductions in consumer prices and the cost of living. More broadly, we find that the impact of foreign productivity growth on domestic welfare is relatively modest compared to that of domestic productivity, especially for a large country such as the United States, for which trade is a relatively small share of expenditure.

Overall, our findings highlight that changes in countries relative incomes are potentially quite misleading for their welfare, and that while domestic productivity is far from everything, it plays a large role in determining domestic living standards.

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