Romer or Ricardo?

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Abstract

How much trade and growth comes from distinct varieties (Romer) versus quality differences (Ricardo)? How important is new variety creation versus creative destruction for productivity differences and growth? How much growth comes from innovation at home versus abroad? We write down a multi-country model of trade and growth featuring these forces and draw out testable implications for the behavior of export and import growth rates across product categories. We infer that Ricardian and Romerian forces are both important for trade and growth. But the U.S. innovates mostly by creating new varieties and improving its own products, whereas developing countries such as China grow mostly by creatively destroying the products of rich countries. For small countries the vast majority of growth comes from innovation abroad.

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1. Introduction

Many theories of growth revolve around the creation of new varieties in the vein of Romer (1990). Other theories feature quality improvements upon existing varieties, often involving creative destruction, such as in Aghion and Howitt (1992) and Grossman and Helpman (1991a). These same branches coexist in the trade literature: Krugman (1980), Rivera-Batiz and Romer (1991), and Melitz (2003) model trade in horizontal varieties, whereas Grossman and Helpman (1991a,b), Eaton and Kortum (2002), and Bernard, Eaton, Jensen and Kortum (2003) emphasize trade due to vertical differentiation in quality and productivity.

The Romer and Aghion-Howitt/Grossman-Helpman branches in growth, and the Melitz and Eaton-Kortum branches in trade, continue to thrive alongside each other. This begs the question: how important are differentiated varieties versus Ricardian productivity differences in accounting for growth and trade? How much do varieties versus quality levels contribute to aggregate productivity differences across countries? And how much does a given country's growth come from innovations abroad versus at home?

We write down a model of trade and growth featuring both Melitz variety and Eaton-Kortum quality ladder components, and in which ideas spill over across countries when a country improves upon a product it imports from another country. In the model, the innovation rates determine growth rates, TFP differences across countries, and the nature of trade. Because ideas spill over across borders, all countries grow at the same rate as determined by innovation rates in *all* countries. A country's innovation rate relative to that of other countries affects its relative TFP but not its growth rate.

A country that innovates primarily by creating new products will end up exporting differentiated products in steady state, while a country that innovates by moving up the quality ladder will export products in which it has a Ricardian comparative advantage. The rate at which countries move up the quality ladder also determines the life-cycle of a product. All products are born as differentiated varieties, but the technology diffuses across countries as other countries improve upon their imports. A product starts out as a differentiated variety but becomes a Ricardian product over time. Moreover, products become "more" Ricardian with age, as more and more countries acquire the blueprint to produce the variety. This same process determines the reallocation of products across countries over the life-cycle of a product.

In sum, innovation rates determine aggregate growth, TFP differences across countries, Romerian vs. Ricardian trade in the steady state, and the product life-cycle. We use the model to identify the patterns each type of innovation should leave in the data. More specifically, we look at export and import growth rates by country and product category. New varieties will tend to show up as new export categories or rapid export growth in a category in the inventing country. Creative destruction of another country's products, in contrast, will simultaneously fuel positive export growth and negative import growth in a country-category. More subtly, quality improvements on existing products within a country should lead to modest export growth without a concomitant shrinkage of a country's imports in the category.

We conduct indirect inference by simulating a model of 20 trading economies, and compare its quantitative predictions to data on trade flows at the 4-digit SITC level in the 20 countries from 1991 to 2016. These 20 countries (one of which is actually the EU) account for about 95% of world trade. We use moments from the Feenstra, Lipsey, Deng, Ma and Mo (2005) dataset to infer the rate of domestic new variety creation and the rate of domestic creative destruction upon imported products for each country.

We arrive at five key findings. First, a majority of trade is Ricardian (68%) rather than the Romerian (32%). At the extremes, U.S. exports are 87% Romerian, whereas Chinese exports are 99% Ricardian. Second, products typically migrate from the U.S. to other rich countries, and only later to developing countries, via creative destruction over their life cycle. Third, income differences stem from differences in the number of varieties produced rather than differences in average product quality. Fourth, 50% of world growth comes innovation on imports and 32% from the creation of new Romerian products. Fifth and finally, around one-half (44%) of growth comes from innovations abroad, though less for the U.S. (26%) and more for small countries (80% to 90%).

Our effort relates to a number of prior studies. This includes Grossman and Helpman (1991a,b), who modeled the creation of new products in the "North" and their subsequent migration to the "South" via imitation. With the exception of China, however, our results contradict the widely held belief that new varieties are created in the rich countries and then move to poor countries.[1] Regarding the relocation of products from the U.S. to China, Autor, Dorn and Hanson (2013, 2016) document the impact of competition from Chinese imports on employment in the U.S.[2] Our results suggest instead that products more commonly migrate from to other rich countries before being produced in China.

Hsieh, Klenow and Nath (2021) use a two-country model with only creative destruction to study the impact of cross-country idea flows on the gains from trade. We generalize their model to many countries and allow new variety creation. Like us, Buera and Oberfield (2020) study the role of international trade in technology diffusion and overall growth in a multi-country setting. Their focus is on conditions that yield a Fréchet distribution and make their model fall into the Eaton-Kortum class of Ricardian trade. Eaton and Kortum (2001) provide a unified Ricardian treatment of trade and growth without international technology diffusion. Unlike these studies, we add new variety creation, which prevents us from obtaining a Fréchet distribution of quality within countries. Perla, Tonetti and Waugh (2021) model both variety creation and quality growth, but do not incorporate international technology diffusion. Lind and Ramondo (2022) model international diffusion in a general setting, and provide analytical solutions as well as testable predictions for expenditure patterns. They likewise predict that a product's substitutability rises over time with global diffusion.

[1]See for example Feenstra and Rose (2000).

[2]Martin and Mejean (2014) demonstrate the impact of low-wage competition on the quality of products exported by France.

Importantly, none of the prior studies looks at the dynamics of import and export growth across categories within countries to shed light on the sources of trade and growth. We build on Hanson, Lind and Muendler (2018) in looking at data on trade dynamics as a window into evolving comparative advantage.

The rest of the paper is organized as follows. Section 2 lays out our multi-country model of trade with variety creation and quality growth. The next section describes how we infer the sources of innovation in each country from its distribution of export and import growth rates across product categories. Section 4 lays out the trade and TFP data we use. In Section 5 we present our parameter estimates, and in Section 6 we draw out implications for the sources of trade, TFP levels, and TFP growth across countries. We conclude in Section 7.

2. Model

This section presents a multi-country model of trade and growth. The static trade component of the model features both trade in differentiated products and trade due to Ricardian comparative advantage for a given product. In the dynamic portion of the model countries innovate by climbing up quality ladders and by introducing new products. The share of trade in differentiated products versus the share of trade from Ricardian comparative advantage is an endogenous outcome of the creation of new products by the country and the rate at which it steals products from other countries.

2.1 Static equilibrium

Aggregate consumption in country k is given by a CES combination of products

$$C_k = \left(\sum_{j \in W} \sum_{i \in J_{jk}} \left(q_{ij} \, C_{ijk} \right)^{1-\frac{1}{\sigma}} \right)^{\frac{\sigma}{\sigma-1}}$$

where C_{ijk} is consumption of product i from country j sold in country k, q_{ij} is quality (or equivalently process efficiency), J_{jk} is the set of country j's products sold in country k, and W is the set of countries in the world.

We assume a product is made with one unit of labor and that firms pay a fixed cost f in units of domestic labor to sell that product in the domestic market. This overhead cost allows the highest quality producer to charge the monopoly markup $\frac{\sigma}{\sigma-1}$, as the next lowest quality competitor will be deterred by zero ex post profits under Bertrand competition. The overhead cost also determines a cutoff quality — varieties below the threshold have negative present discounted value, and therefore exit endogenously. The quality cutoff rises with wage growth, ensuring a stationary distribution of quality across varieties within each country (relative to generalized mean quality in each country).

The fixed cost of selling a product in the foreign market is f in units of labor of the *destination* country. The product will only be sold in country k when gross profits exceeds the fixed cost of selling in country k. After we impose profit maximization, the cutoff quality q_j^k in the foreign market is

$$q_j^k \equiv \frac{\sigma}{\sigma-1}\frac{w_j\,\tau_k^{\frac{\sigma}{\sigma-1}}}{P_k}\left[\frac{f(\sigma-1)\left(1-\frac{\tau_k-1}{\tau_k}x_k\right)}{L_k}\right]^{\frac{1}{\sigma-1}} \quad \text{for } k \neq j \tag{1}$$

where w_j denotes the nominal wage in country j, P_k is the CES price index in country k, $\tau_k \geq 1$ is the gross trade cost faced by all countries (except for producers in country k) selling to country k, x_k is the trade share in country k's output, and L_k is total labor supply in country k. The cutoff quality for domestic producers q_j^j is also given by equation (1) after τ_k outside the square brackets is set to 1. The cutoff quality q_j^k is increasing in the source country's wage w_j and decreasing in the destination country's size L_k. A rising wage in the producer's country thus also increases the quality cutoff for products imported from that country, and induces the endogenous exit of low quality imports.

We now distinguish between "Romerian" and "Ricardian" products. Country j's Romerian products are those products for which only country j has the blueprint. As in Melitz (2003), a Romerian product is sold in every market where the variable profit covers the fixed cost. The set of countries where this is the case is defined by

$$K_{ij}^{Rm} \equiv \{k \in W \mid q_{ij} > q_j^k\} \tag{2}$$

where the cutoff q_j^k is given by equation (1). Product i from country j is sold in more countries when q_{ij} is larger, the wage of the exporting country w_j is lower, and the destination country is larger.

A Ricardian product is one where more than one country has the blueprint. A Ricardian product from j is sold in country k if two conditions are met. First, as is the case with a Romerian product, profits have to exceed the fixed cost. Second, as in any model of trade from Ricardian comparative advantage, j also has to be the lowest cost seller into country k among all the countries with the blueprint for the same product. The set of countries in which country j sells a Ricardian product i is thus defined as:

$$K_{ij}^{Rd} \equiv \left\{ k \in W \,\middle|\, j = \arg\min_{\ell \in \widetilde{K}_{ik}} \left\{ \frac{\tau_k w_\ell}{q_{i\ell}} \right\} \right\} \tag{3}$$

where $\tau_k = 1$ for $j = k$ and $\widetilde{K}_{ik}$ denotes the set of countries with blueprints for product i and where $q_{i\ell}$ exceeds the threshold for selling in country k.[3]

The set of products country j sells to country k is then given by

$$J_{jk} \equiv \{i \in P_j^{Rm} \mid k \in K_{ij}^{Rm}\} \;\cup\; \{i \in P_j^{Rd} \mid k \in K_{ij}^{Rd}\} \tag{4}$$

where P_j^{Rm} and P_j^{Rd} are the set of country j's Romerian and Ricardian products and the sets K_{ij}^{Rm} and K_{ij}^{Rd} are defined by equations (2) and (3). The first term in (4) denotes country j's Romerian products sold in country k; the second term is j's Ricardian products where country j is the lowest cost supplier in country k.

[3] Formally $\widetilde{K}_{ik} \equiv \{\ell \in W \mid q_{i\ell} > q_j^k\}$.

The distribution of wages in the world is pinned down by each country's set of products P_j^{Rm} and P_j^{Rd}, the quality cutoffs of each bilateral pair given by equation (1), the pattern of trade defined by equations (2), (3), and (4), and the condition that aggregate labor demand is equal to labor supply and total exports are equal to total imports for each country. Given a distribution of wages around the world, the real consumption wage is then given by

$$\frac{w_k}{P_k} = \frac{\sigma - 1}{\sigma} M_k^{\frac{1}{\sigma-1}} \widetilde{Q}_k$$

where M_k is the number of products sold in country k and

$$\widetilde{Q}_k \equiv \left[\frac{1}{M_k} \sum_{j \in W} \sum_{i \in J_{jk}} \left(\frac{w_k}{w_j \tau_k} q_{ij} \right)^{\sigma-1} \right]^{\frac{1}{\sigma-1}}$$

is the quality of the representative product consumed in country k weighted by the relative wage and the trade cost. For a given distribution of trade cost and relative wages, the real wage is increasing in the number of products consumed and the power mean of the quality of these products.

2.2 Innovation

We now introduce dynamics. Aggregate growth comes from moving up the quality ladder of existing products as in Grossman and Helpman (1991a), Aghion and Howitt (1992), and Klette and Kortum (2004), and from the creation of new products as in Romer (1990). Both types of innovation can come from domestic as well as foreign innovators.

Table 1 lists the arrival rates of each type of innovation from innovators in country j. Domestic innovators improve upon domestic products with probability λ_j *for each produced variety*, where the quality drawn by the innovator follows a Pareto distribution with shape parameter θ and a scale parameter equal to the existing quality level. Thus, the proportional step size of quality innovation on

Table 1: Channels of Innovation in Country j

	Probability	Scale
Innovation on domestic products	λ_j	1
Innovation on imported products	δ_j	$\min\left[\frac{\alpha_j}{\alpha_k}, 1\right]$
Creation of new products	κ_j	ρ

Note: The improvement in quality of a domestic or imported product follows a Pareto distribution with shape parameter θ and scale parameter 1 (for a domestic product) or $\min\left[\frac{\alpha_j}{\alpha_k}, 1\right]$ (for a product in j imported from k). The quality of a new variety is drawn from the quality distribution of existing products produced by country j multiplied by ρ.

a given variety follows a Pareto distribution with shape parameter θ and scale parameter 1. The average proportional improvement in quality on an existing variety, conditional on innovation, is thus $\left(\frac{\theta}{\theta-(\sigma-1)}\right)^{1/(\sigma-1)} > 1$.

Domestic innovators also innovate upon imported products with probability δ_j *for each imported variety*. The quality drawn by the innovator in j on an import from country k follows a Pareto distribution with shape parameter θ and a scale parameter equal to the product of the existing quality level and $\min\left[\frac{\alpha_j}{\alpha_k}, 1\right]$. Thus, the proportional step size of quality innovation on a given variety follows a Pareto distribution with shape parameter θ and scale parameter $\min\left[\frac{\alpha_j}{\alpha_k}, 1\right]$. When $\frac{\alpha_j}{\alpha_k} < 1$, quality of the innovator can be lower than the existing quality because of imperfect spillovers of knowledge across borders.

Domestic innovators also create brand new varieties at rate κ_j. This arrival rate is per each of the country's produced varieties. The quality of a new variety is drawn randomly from the quality distribution of domestically produced products multiplied by a constant $\rho \leq 1$. The parameter ρ thus captures the extent to which the quality of new varieties differs from that of existing ones.

Table 2 shows the arrival rates in country j implied by the innovation rates in Table 1 *from all source countries*. Quality improvements and new products can come from innovation by domestic firms (shown in column 1) as well as from innovation by foreign firms (shown in column 2). The first row shows the probability that a product exported by country j moves up its quality ladder. The odds that this occurs from domestic innovation is λ_j[4]

The quality of an exported product can also increase from foreign innovation, and the probability a foreign innovator innovates upon this product is δ_k. But the foreign innovator will not necessarily replace the domestic incumbent, as this also depends on the relative α, the relative wage and the trade cost. Since the quality step size follows a Pareto distribution, the probability that the quality improvement from the innovator in foreign country k is large enough to replace the incumbent in j is $\left(\min\left[\frac{\alpha_j}{\alpha_k},1\right]\cdot\frac{w_j}{\tau_j w_k}\right)_m^\theta \equiv \max\left[\left(\min\left[\frac{\alpha_j}{\alpha_k},1\right]\cdot\frac{w_j}{\tau_j w_k}\right)^\theta,1\right]$. The probability that the foreign innovator takes over the domestic market is higher when α in the foreign country is high relative to α in the home country, the foreign innovator is in a low-wage country, when the incumbent producer is in a high-wage country, and when the trade cost is low.

If the foreign country does not import the product and only produces it for domestic consumption, the foreign innovator will innovate upon its own blueprint for the product with probability λ_k. In this case, the innovator will replace the incumbent in country j with probability $\left(\frac{w_j\, q_{ik}}{\tau_j\, w_k\, q_{ij}}\right)_m^\theta$. The probability that a product exported by j is improved upon by *any* foreign innovator is a weighted sum of $\delta_k\left(\frac{w_j}{\tau_k w_k}\right)_m^\theta$ for the foreign countries that import the product from j and the sum of $\lambda_k\left(\frac{w_j\, q_{ik}}{\tau_j\, w_k\, q_{ij}}\right)_m^\theta$ for the countries that do not import the product. This sum is shown in row 1, column 2 in Table 2.

The second and third rows show the probabilities of quality improvement of non-traded and imported varieties in country j. The probability that a domestic innovator innovates upon a non-traded variety and replaces the incumbent is again given by λ_k. The probability that a domestic innovator in country j inno-

[4]We do not take a stand on how much domestic innovation on domestically produced products is by the incumbent producer or another domestic firm. If it is another firm it will replace the domestic incumbent with probability one.

Table 2: Arrival rate of quality improvement and new products in country j

	Domestic Innovation	Foreign Innovation
Existing Products in j		
Exported by j	λ_j	$\delta_j^* \equiv \sum_{k \in W \neq j} \begin{pmatrix} \widetilde{\alpha}_{jk}\, \lambda_k \left(\frac{w_j\, q_{ik}}{\tau_j\, w_k\, q_{ij}} \right)_m^\theta + \\ \alpha_{jk}\, \delta_k \left(\min\left[\frac{\alpha_k}{\alpha_j}, 1 \right] \frac{w_j}{\tau_j\, w_k} \right)_m^\theta \end{pmatrix}$
Non-traded	λ_j	$\lambda_j^* \equiv \sum_{k \in W \neq j} \begin{pmatrix} \beta_{jk}\, \lambda_k \left(\frac{w_j\, q_{ik}}{\tau_j\, w_k\, q_{ij}} \right)_m^\theta + \\ \sum_{\ell \in W \neq j,k} \beta_{jk\ell}\, \delta_\ell \left(\min\left[\frac{\alpha_\ell}{\alpha_k}, 1 \right] \frac{w_j q_{ik}}{\tau_j w_\ell q_{ij}} \right)_m^\theta \end{pmatrix}$
Imported by j	$\widetilde{\delta}_j \equiv \delta_j \sum_k \gamma_{jk} \left(\min\left[\frac{\alpha_j}{\alpha_k}, 1 \right] \frac{\tau_j\, w_k}{w_j} \right)_m^\theta$	$\widetilde{\lambda}_j^* \equiv \sum_{k \in W \neq j} \begin{pmatrix} \sum_{\ell \in W \neq j} \widetilde{\gamma}_{jkl} \lambda_\ell \left(\frac{w_k q_{i\ell}}{w_\ell q_{ik}} \right)_m^\theta + \\ \sum_{\ell \in W \neq j,k} \gamma_{jk\ell}\, \delta_\ell \left(\min\left[\frac{\alpha_l}{\alpha_k}, 1 \right] \frac{w_k}{w_\ell} \right)_m^\theta \end{pmatrix}$
New Products in j		
New to world	κ_j	$\kappa_j^* \equiv \sum_{k \in W \neq j} \kappa_k\, P\left(j \in K_{ik}^{Rm} \right)$
New to j only	–	$\widetilde{\delta}_j^* \equiv \sum_{k \in W \neq j} \begin{pmatrix} \eta_{jk}\, \lambda_k \left(\frac{q_{ik}}{q_k^j} \right)_m^\theta + \\ \sum_{\ell \in W \neq j,k} \eta_{jk\ell}\, \delta_l \left(\min\left[\frac{\alpha_l}{\alpha_k}, 1 \right] \frac{w_k}{w_\ell} \frac{q_{ik}}{q_\ell^j} \right)_m^\theta \end{pmatrix}$

Note: $(x)_m^\theta \equiv \min\left[(x)^\theta, 1 \right]$. $\widetilde{\alpha}_{jk}$ is the number of country j's exported products also produced in country k as a share of the total number of j's exported products. α_{jk} is the number of country j's exported products supplied to country k as a share of the total number of j's exported products. β_{jk} is the number of country j's non-traded products also produced in country k as a share of the total number of country j's non-traded products. β_{jkl} is the number of country j's non-traded products also produced in country k and exported from country k to country ℓ as a share of the total number of country j's non-traded products. $\widetilde{\gamma}_{jk\ell}$ is the number of country j's imported products supplied by country k and also produced in country ℓ (as a non-traded product if $\ell \neq k$) as a share of country j's imported products. $\gamma_{jk\ell}$ is the number of country j's imported products supplied by country k and also imported by country ℓ as a share of country j's imported products. η_{jk} is the number of products not consumed in country j but produced in country k as a share of the total number of country j's non-consumed products. $\gamma_{jk\ell}$ is the number of products not consumed in country j but exported from country k to country ℓ as a share of country j's non-consumed products. $P\left(j \in K_{ik}^{Rm} \right)$ is the probability that the quality of new Romerian product i of country k exceeds the quality threshold in country j.

vates upon a variety imported from country k and replaces the foreign incumbent is $\delta_j \left(\min\left[\frac{\alpha_j}{\alpha_k},1\right]\frac{\tau_j w_k}{w_j}\right)_m^\theta$. This probability is decreasing in the wage of country j relative to that of country k. Conditional on innovation, a high wage country is not likely to replace its imports from the low wage country. For example, U.S. innovators may innovate upon products imported from China, but producing these products is not likely to be viable with U.S. wages. On the other hand, a low wage country is much more likely to replace its imports from a high wage country conditional on innovation (though a low wage country may innovate less often).

Finally, the probability of quality improvements on non-traded and imported varieties due to a foreign innovation is a weighted sum of λ_k and δ_k, as it was the case with foreign innovations on exports. Again, note that a foreign innovator is more likely to replace the incumbent the lower the innovating country's wage is relative to the incumbent country's wage.

The last two rows in Table 2 show the arrival rate of new products. In particular, the second to last row gives the rate at which products enter country j due to creation of new products. Innovators in the home country j create new products at rate κ_j. Innovators in foreign countries also create new products. The arrival rate of foreign products from any foreign country is the sum of κ for all the other countries in the world, weighted by the probability that profits from the new product is sufficient to cover the fixed cost in country j.

The last row shows the arrival rate of products that are new to country j but that are not new to the world. This occurs when there are some newly created products that are not immediately sold in country j because their quality does not exceed the quality threshold. After such products are improved upon by another country, the profits from selling this product may increase by enough to meet the fixed cost of selling in country j. This event is likely to be larger in a small country where many products are not sold because the profits from selling to the small market does not justify the fixed cost. This event is also more likely when a low wage country innovates upon its imports from a high wage country.

The expected growth rate of the real consumption wage in j is a function of Table 2 arrival rates as follows:

$$\mathbb{E}\left[(1+g_j)^{\sigma-1}\right] = 1 + \underbrace{\left(x_j^x + x_j^n\right)\lambda_j S_{\lambda_j} + x_j^x \delta_j^* S_{\delta_j^*} + x_j^n \lambda_j^* S_{\lambda_j^*}}_{\text{quality improvement on domestic products}}$$
$$+ \underbrace{x_j^m \left[\widetilde{\delta}_j S_{\widetilde{\delta}_j} + \widetilde{\lambda}_j^* S_{\widetilde{\lambda}_j^*}\right]}_{\text{quality improvement on imports}} + \underbrace{\left(x_j^x + x_j^n\right)\left[\kappa_j S_{\kappa_j} + \kappa_j^* S_{\kappa_j^*}\right] + x_j^o \widetilde{\delta}_j^* S_{\widetilde{\delta}_j^*}}_{\text{new varieties}} \tag{5}$$
$$- \chi_j S_{\chi_j} - \chi_j^* S_{\chi_j^*}$$

where x_j^x, x_j^n, x_j^m, and x_j^o denotes the number of exported, non-traded, imported, and non-consumed products in country j; S_{λ_j}, $S_{\delta_j^*}$, $S_{\lambda_j^*}$, $S_{\widetilde{\lambda}_j^*}$, $S_{\kappa_j^*}$, S_{κ_j}, and $S_{\widetilde{\delta}_j^*}$ denote the change in the inverse of the quality-adjusted price of the innovated (or new) product relative to the quality-adjusted price of the average consumed product (raised to $\sigma - 1$);[5] χ_j and χ_j^* denote the number of exiting domestic and foreign products; and finally, S_{χ_j} and $S_{\chi_j^*}$ denote the average quality-adjusted price of the exiting products.

Equation (5) says that aggregate growth in the consumption wage in country j is the sum of the contribution of quality upgrading on domestic products (first term), quality upgrading on imported products (second term) and, the introduction of new products (third term), net of the effect of exit from obsolescence (last two terms). Quality upgrading on domestic products is increasing in the rate at which domestic innovators improve upon their own products, λ_j, the probability that foreign innovators improve upon country j's products, δ_j^* and λ_j^*, and the quality-adjusted price of the innovated products, S_{λ_j}, $S_{\delta_j^*}$, and $S_{\lambda_j^*}$. Likewise, the contribution of quality upgrading on imported products is increasing in the rate at which domestic and foreign innovators improve upon these products, $\widetilde{\delta}_j$ and

[5]For example, $S_{\lambda_j} \equiv \left[\frac{\theta}{\theta-(\sigma-1)} - 1\right]\left(\frac{\widetilde{q}_j^d}{\widetilde{q}_j}\right)^{\sigma-1}$ is the product of the average improvement in quality and the ratio of the quality of the representative domestic product to the quality of the representative consumed product (raised to $\sigma - 1$).

$\widetilde{\lambda}_j^*$, and their quality-adjusted price post-innovation. The third term in equation (5) is the contribution of new products, which is increasing in the rate at which domestic and foreign innovators create new products, κ_j, κ_j^*, and $\widetilde{\delta}_j^*$, and the quality-adjusted price of the new products. Finally, the last two terms in equation (5) is the loss from exit of domestic and foreign products due to the rising real wage, which are the product of the exit rate and the average quality-adjusted price of the exiting products.

The change in a product's quality-adjusted price depends on the step-size of innovation and the change in the labor cost when the product is reallocated across countries. The former depends on the gap in α and the latter on the the wage gap. Specifically, when country j successfully innovates upon an imported by country k, the expected proportional change in the quality-adjusted price of the innovated product in country j is

$$\frac{\theta}{\theta - (\sigma - 1)} \max \left\{ 1, \left(\min \left[\frac{\alpha_j}{\alpha_k}, 1 \right] \frac{\tau_j w_k}{w_j} \right)^{\sigma-1} \right\}.$$

When $\alpha_j < \alpha_k$, the change in quality is proportional to $\left(\frac{\alpha_j}{\alpha_k}\right)^{\sigma-1}$ so the change in the quality-adjusted price is proportional to $\left(\frac{\alpha_j}{\alpha_k}\frac{w_k}{w_j}\right)^{\sigma-1}$.[6] When a low-wage country innovates upon a product from a high-wage country, the change in the quality-adjusted price of an innovated product can be large if gap in α between the two countries is small. However, if knowledge flows between poor and rich countries are imperfect, which we represent as a low α in the low wage country relative to the high-wage country, then innovation by the low wage country on a high-wage country's product will result in a much smaller change in the quality-adjusted price.

We can rearrange equation (5) to express growth from domestic versus foreign

[6] Assuming $\frac{\alpha_j}{\alpha_k} \frac{\tau_j w_k}{w_j} < 1$.

innovation:

$$\mathbb{E}\left[(1+g_j)^{\sigma-1}\right] = 1 + \underbrace{\left(x_j^x + x_j^n\right)\lambda_j\, S_{\lambda_j} + x_j^m\, \widetilde{\delta}_j\, S_{\widetilde{\delta}_j} + \left(x_j^x + x_j^n\right)\kappa_j\, S_{\kappa_j}}_{\text{domestic innovation}}$$
$$+ \underbrace{x_j^x\, \delta_j^*\, S_{\delta_j^*} + x_j^n\, \lambda_j^*\, S_{\lambda_j^*} + x_j^m\, \widetilde{\lambda}_j^*\, S_{\widetilde{\lambda}_j^*} + \left(x_j^x + x_j^n\right)\kappa_j^*\, S_{\kappa_j^*} + \widetilde{\delta}_j^*\, S_{\widetilde{\delta}_j^*}}_{\text{foreign innovation}} \tag{6}$$
$$- \chi_j\, S_{\chi_j} - \chi_j^*\, S_{\chi_j^*}.$$

Domestic innovators contribute to growth by improving upon domestic and imported products, and by creating new varieties. Foreign innovators contribute to country j's growth by improving upon country j's products, their exports to country j, by creating new varieties that they sell in country j, and by creatively destroying a high-wage country's products that were previously not sold in country j.

In a steady state, all countries grow at the same rate and differences across countries in the arrival rates of innovation show up as differences in the real wage. In the empirical section of the paper we will show the contribution of the three sources of innovation to cross-country TFP gaps. We will also use equation (5) to decompose the contribution of foreign versus domestic innovation to each country's growth, and equation (6) to decompose the role of quality upgrading versus new products to growth.

The arrival rates of innovation also determine the share of Romerian versus Ricardian trade and the product life-cycle. The share of Romerian versus Ricardian trade of each country is determined by the rate at which new varieties are created in the country versus the rate at which the country improves upon its imports. It is easiest to see this in simplified model with two countries and no trade costs. In this case, the net arrival rate of a Romerian export in country j is:

$$\kappa_j \;-\; \text{Romer Share}_j\, \delta_k \left(\frac{w_j}{w_k}\right)_m^{\theta}$$

And the net arrival rate of a Ricardian export is

$$\delta_j \left(\frac{w_k}{w_j}\right)_m^{\theta} - \text{Ricardo Share}_j \, \delta_k \left(\frac{w_j}{w_k}\right)_m^{\theta}$$

In a steady state the net arrival rate of a Romerian product is equal to the net arrival rate of a Ricardian product, which is the case when the ratio of the share of Romerian products to the share of Ricardian products is:

$$\frac{\text{Romer Share}_j}{\text{Ricardo Share}_j} = \frac{\kappa_j}{\delta_j \left(\frac{w_k}{w_j}\right)_m^{\theta}}$$

The share of Romerian products in country j is increasing in κ_j and w_j/w_k and decreasing in δ_j.

The same innovation rates also determine the life-cycle of a product. First, all new products are by definition Romerian and gradually become Ricardian products after they are innovated upon and replaced by producers in other countries. Thus the rate at which a given cohort of products switches from Romerian to Ricardian products depends on the rate at which innovators from all countries improve upon imports. Second, the same forces that determine the steady-state share of Romerian products in a country's exports also determines the share of the country in a product's life-cycle. Countries that primarily innovate by creating new varieties will have a large Romerian share in steady-state, and will see its share of a cohort of products fall as its products are innovated upon by other countries. Countries that primarily innovate by improving their imports will have a low Romerian share in steady-state, and will see its share increase over the product's life-cycle.

In sum, the innovation probabilities in each country (κ, λ, δ), the parameters governing the quality-adjusted price of the innovated products (θ, σ, α, and ρ), and the trade cost (τ) pin down the common global growth rate and the product life-cycle. These parameters also pin down the real consumption wage, the share of growth from quality upgrading and new varieties, the share of growth from domestic versus foreign innovation, the importance of Romerian versus Ricardian trade in each country. In the next section we will show how we infer these parameters from the distribution of export growth and import declines.

3. Innovation and Trade Dynamics

We now show how we infer the relative importance of different sources of innovation from the distribution of export and import growth. We consider three sources of innovations affecting the export and import growth distributions of a country: innovation on its own exports (due to λ), creation of new varieties (due to κ), and innovation on imports (due to δ).

First, suppose a country innovates on an exported product with expected step size S. The expected change in exports is $S^{\sigma-1} - 1$. The expected growth rate of exports of the product, defined as the change in exports of the product divided by the average of the product's exports prior and after innovation, is $2\frac{S^{\sigma-1}-1}{S^{\sigma-1}+1}$.

Now suppose instead the innovators in j create a brand new product. The growth rate of export, again defined as the change in export of the product divided by the average of the product's exports prior and after innovation, is 2. As long as the step size is not too large, the growth rate of an exported product is larger when innovators create new products compared to when the country improves upon its existing exports.

Third, consider the case when the country improves upon and replaces the incumbent producer of an imported product in the foreign market. Again, the growth rate of export in the newly exported variety is 2, which is the same as the growth rate when the country creates new products. Consider however the effect of δ_j on the foreign country's exports. The foreign country loses an exported product to the home country, so exports of the home country rise and its imports from the foreign country falls. In contrast, exports of the foreign country do not change when the home country creates new products.

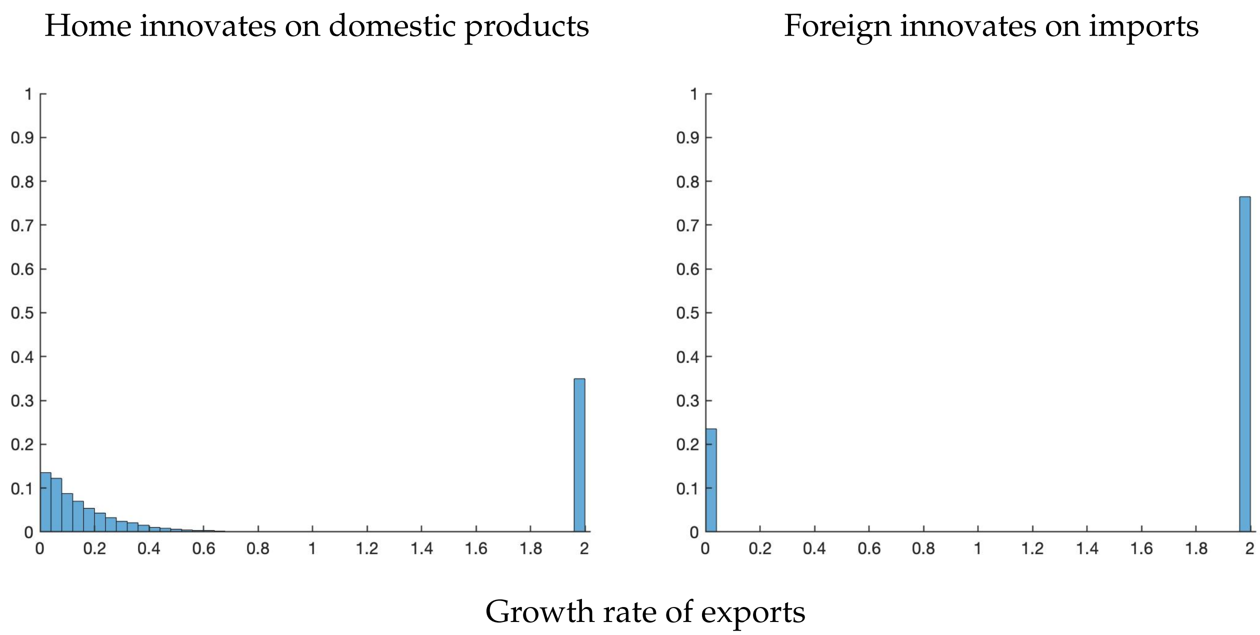
Finally, consider the effect of knowledge spillovers from high wage to low wage countries on the probability a low wage country replaces the incumbent producer of an imported product from another low wage country compared to an import from a high wage country. If α in the low wage country is similar to that in the high wage country, the low wage country is then more likely to replace an import from a high wage country compared to an import from another low wage country. On the other hand, if a low wage country is more likely replace an import from another low wage country, then this suggests that the low wage country finds it harder to build upon ideas from high wage countries compared to ideas from the low wage country.

To recap, a country that is successful in innovating will see its exports grow, where the magnitude of the export growth depends on whether the country innovated by improving upon its own products (λ) or via the combination of creating new products (κ) and improving upon the products made by other countries (δ). At the same time, its import growth depends on whether innovation takes the form of new product creation (κ) or taking over another country's exports (δ). Finally, the growth of a low wage country's imports from low-wage vs high-wage countries depends on the extent to which low wage countries are able to build upon the ideas of high wage countries. We will use this idea in our data inference. To illustrate this, we now highlight the predictions of three polar models, each with one main source of innovation, on trade dynamics.

3.1 Distribution of exports and imports in polar models

Consider a polar two-country model where the home country mostly innovates by improving its own products and the foreign country mostly innovates by innovating upon its imports (the home country's exports). In this polar model, the home country's exports grow when it improves upon these exports, and the foreign country's exports grow when it innovates upon its imports. Both countries also engage in a minimal amount of new product creation, which we need to keep the number of products constant since rising wages leads to the exit of low quality products.[7]

Figure 1: Distribution of export growth, λ vs. δ



Note: Figure shows the simulated distribution of export growth for products with positive growth in a model with two countries with the same real wage and zero trade costs. Export growth is the change in exports of a product divided by average exports of the product at the beginning and end of each period. Vertical axis gives the share of products associated with products at each level of export growth. Left panel is home country which mostly innovates on its own products ($\lambda_j = .6$, $\delta_j = .01$, $\kappa_j = .04$). Right panel is foreign country which mostly innovates on its imports ($\lambda_k = 0$, $\delta_k = .9$, $\kappa_k = .04$).

Figure 1 shows the predictions of this polar model for the distribution of positive export growth across products in the two countries. Putting aside the concentration of positive export growth at +2 due to new product creation and previously non-traded products becoming exported after innovations, the distribution of export growth across products in the home country, shown in the left

[7]The arrival rates in this polar model are $\lambda_j = .6$, $\delta_j = .01$, and $\kappa_j = .04$ for the country depicted in the left panel, and $\lambda_k = 0$, $\delta_k = .9$, and $\kappa_k = .04$ for the country shown in the right panel. The polar model also assumes $\tau = 1.02$ and that the relative wage and labor supply are one.

panel in the figure, is concentrated around small changes. In contrast, export growth in the foreign country, shown in the right panel, is concentrated around $+2$ with virtually no mass at smaller changes. This — aside from a small amount of new product creation — reflects the foreign country innovating upon its imports from the home country and starting to export these products.

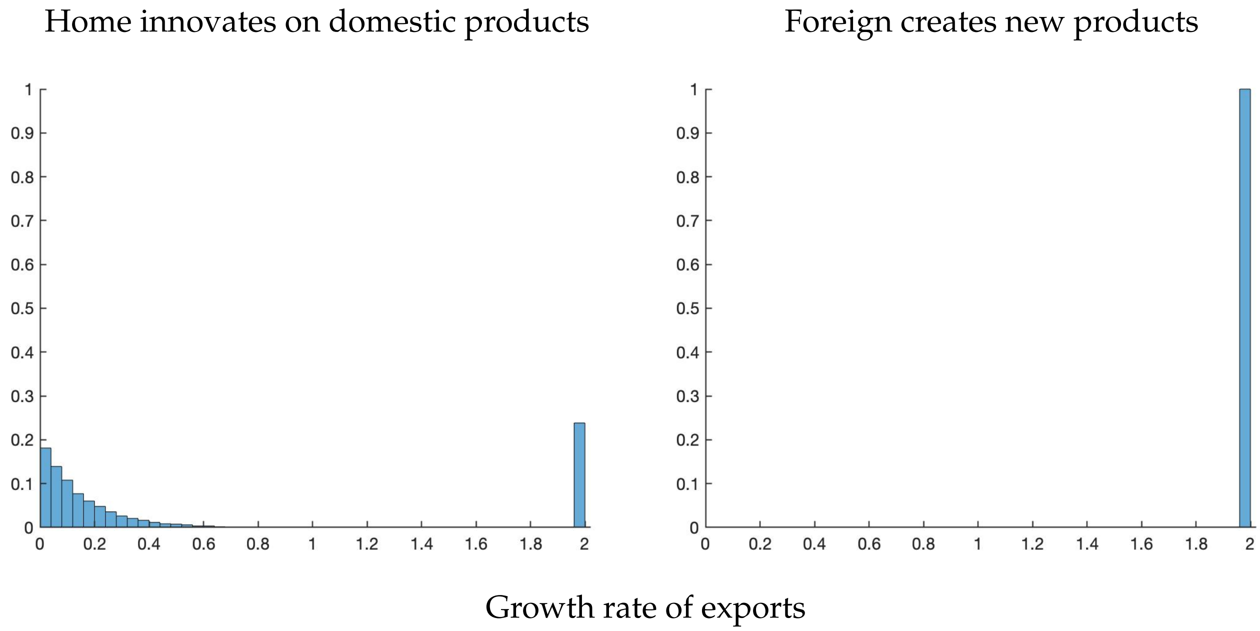
We next show a polar model where the home country still mostly innovates on its own products but the foreign country mostly creates new products.[8] The distribution of positive export growth for the two countries are shown in Figure 2. As can be seen, the distribution of positive export growth in Figure 2 where the foreign country creates new products looks virtually identical to the polar model in Figure 1 where the foreign country innovates on its imports. So the distribution of positive export growth distinguishes between a country that innovates on its own products vs one that innovates on its imports, or a country that innovates on its own products versus one that creates new products. It does not, however, distinguish between a country that innovates on its imports versus one that creates new products.

Consider now a third polar model, where the home country mostly innovates on imports and the foreign country creates new products.[9] As we've seen already, the distribution of positive export growth looks virtually identical in the two cases. Figure 3, on the other hand, shows that the distribution of *import* growth looks very different in the two countries. There is more mass at the extreme of negative import growth (growth rate = -2) in the country that mostly innovates on its imports. There is some mass at growth in imports = -2 in the foreign country as well that comes from the exit of low quality imports from obsolescence, but the mass at import growth = -2 is almost twice as large in the country that innovates on imports. Intuitively, the home country stops importing a product when a

[8]The arrival rates of innovation in this polar model are $\lambda_j = .5125$, $\delta_j = .01$, and $\kappa_j = .04$ for the country shown in the left panel, and $\lambda_k = 0$, $\delta_k = .01$, and $\kappa_k = .2$ for the country in the right panel. We also assume $\tau = 1.02$ and that the relative wage and labor supply are one.

[9]The arrival rates of innovation are $\lambda_j = 0$, $\delta_j = .3$, and $\kappa_j = .04$ in the country depicted on the left panel, and $\lambda_k = 0$, $\delta_k = .01$, and $\kappa_k = .3$ in the country shown on the right panel. We also assume $\tau = 1.02$ and that the relative wage and labor supply are one.

Figure 2: Distribution of export growth, λ vs. κ



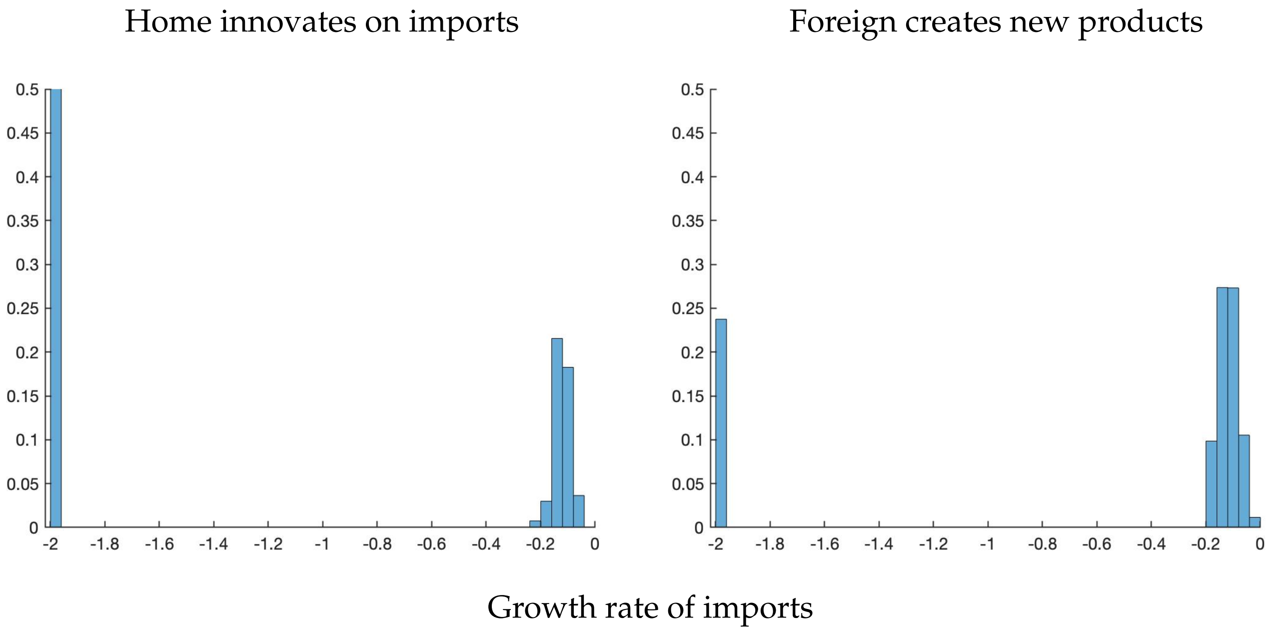
Note: Figure shows the simulated distribution of export growth for products with positive growth in a model with two countries with the same real wage and zero trade costs. Export growth is the change in exports of a product divided by average exports of the product at the beginning and end of each period. Vertical axis gives the share of products associated with products at each level of export growth. Left panel is home country which mostly innovates on its own products ($\lambda_j = .5125$, $\delta_j = .01$, $\kappa_j = .04$). Right panel is foreign country which mostly creates new products ($\lambda_k = 0$, $\delta_k = .01$, $\kappa_k = .2$).

domestic firm innovates upon and replaces the import in the domestic market.

Consider now a fourth polar model where we illustrate the implication of knowledge spillovers from creative destruction by low-wage countries on their imports. The model features two low-wage countries that innovate by improving upon their imports and one high-wage country that mostly creates new varieties.[10] We illustrate the effect of spillovers by comparing the distribution of negative import growth for imports from the rich country with imports from the poor country. Figure 4 shows the distribution of import decline of the low-wage country when the low-wage country always improves upon the quality of its

[10]We target a relative wage of 0.5 and continue to assume zero trade costs.

Figure 3: Distribution of import decline, δ vs. κ

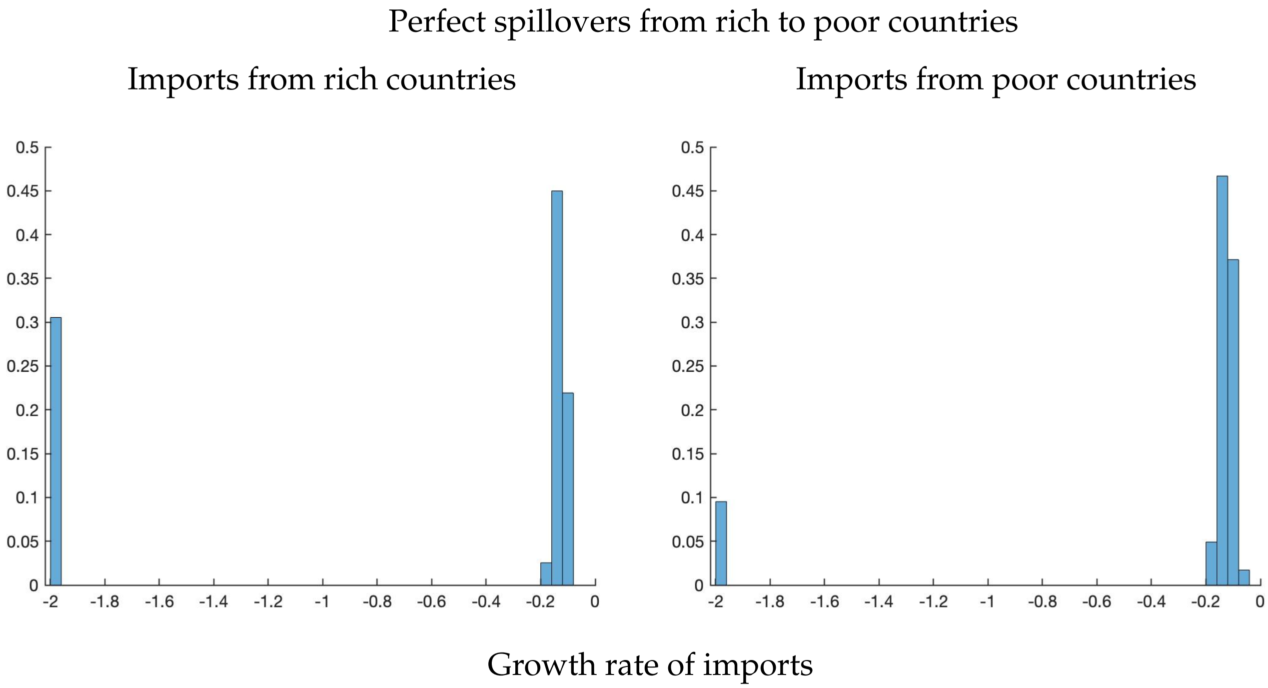


Note: Figure shows the simulated distribution of import growth for products with negative import growth in a model with two countries with the same real wage and zero trade costs. Import growth is the change in imports of a product divided by average imports of the product at the beginning and end of each period. Vertical axis gives the share of products associated with products at each level of import growth. Left panel is home country which mostly innovates on its imports ($\lambda_j = 0$, $\delta_j = .3$, $\kappa_j = .04$). Right panel is foreign country which mostly creates new products ($\lambda_k = 0$, $\delta_k = .01$, $\kappa_k = .3$).

imports from the high-wage country. That is, we assume α is the same in the low-wage and in the high-wage country. Figure **??** shows that with complete knowledge spillovers from rich to poor countries, there is more mass at the extreme of negative import growth for imports from the rich country compared to imports from the poor country.

Figure 5 shows the poor country's distribution of negative import growth with imperfect knowledge spillovers from imports from the rich country. Specifically, when we assume $\alpha_{poor}/\alpha_{rich} = 0.5$, the difference in thickness of the left tail of negative import growth of imports from the rich country compared to imports

Figure 4: Distribution of import decline of imports from rich vs. poor countries



Note: Figure shows the simulated distribution of import growth of a low wage country for products with negative import growth in a model with two low-wage countries, one rich country, zero trade costs, and perfect spillovers of knowledge across countries (α is the same in all countries). Left panel shows the distribution of negative growth of imports from the rich country. Right panel shows the growth distribution of imports from the other poor country. We target a relative wage of 0.5 and assume the two poor countries mostly innovate by improving upon imports, and the rich country mostly creates new products.

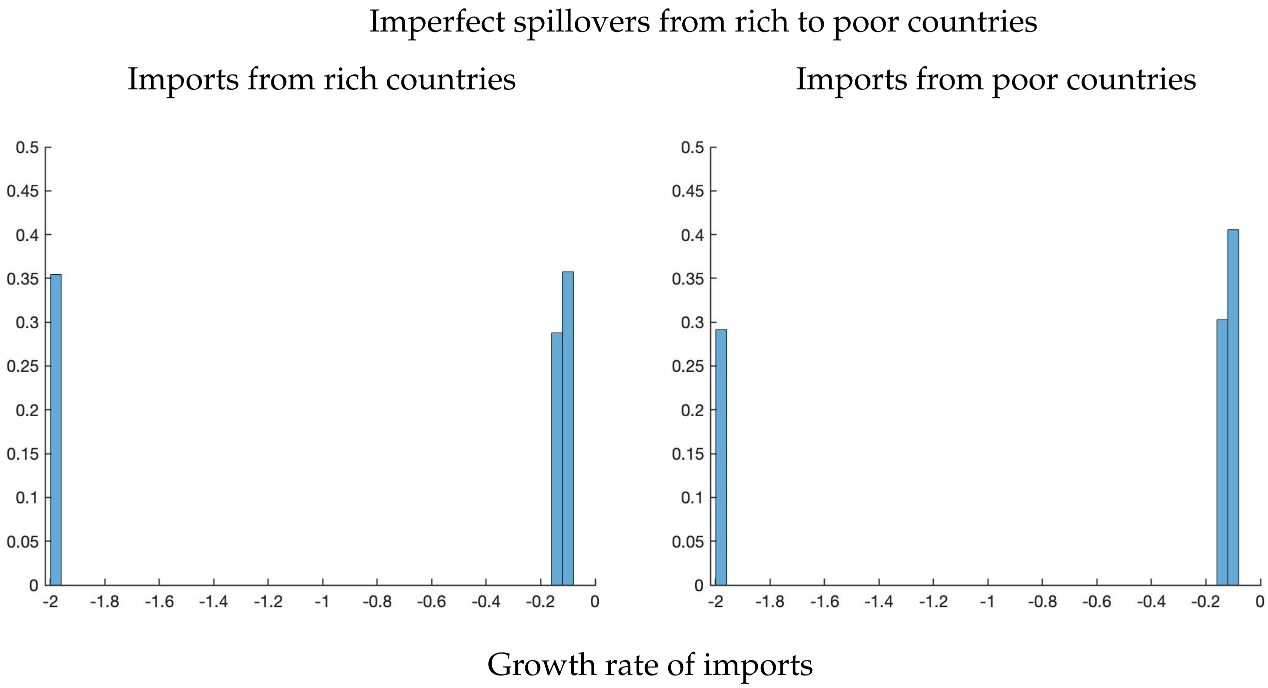
from the poor country is now much smaller.[11]

3.2 Products vs. export categories

We have so far focused on products, as the arrival of innovation on products has clear implications for the distribution of the change in exports and imports of individual products. The problem is that we can track products in the model but not necessarily in the data. In the data we observe export *categories*, such as

[11] We continue to target a relative wage of 0.5 and assume that the low-wage countries innovate by improving upon their imports and the rich country creates new varieties.

Figure 5: Distribution of import decline of imports from rich vs. poor countries

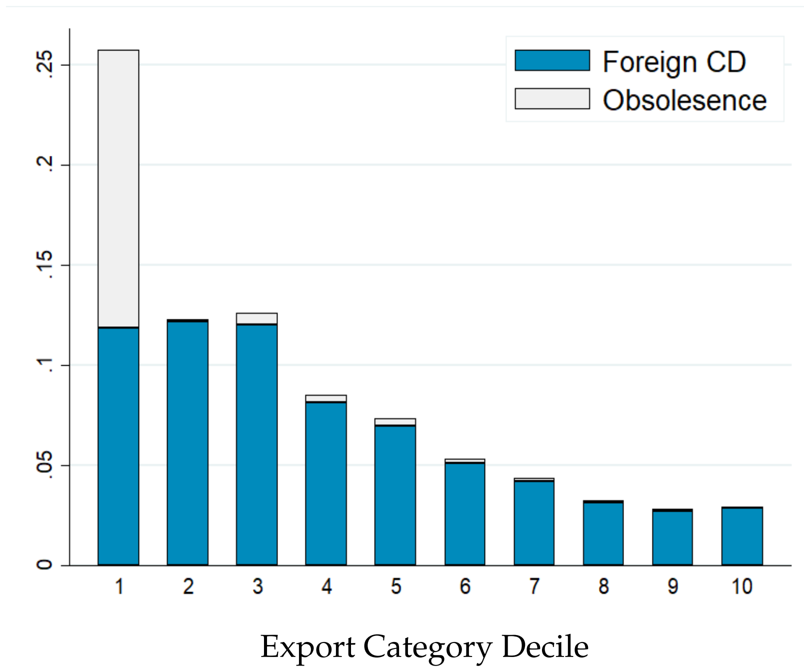


Note: Figure shows the simulated distribution of import growth of a low wage country for products with negative import growth in a model with two low-wage countries, one rich country, zero trade costs, and imperfect spillovers of knowledge across countries ($\alpha_{poor}/\alpha_{rich} = 0.5$). Left panel shows the distribution of negative growth of imports from the rich country. Right panel shows the growth distribution of imports from the other poor country. We target a relative wage of 0.5 and assume the two poor countries mostly innovate by improving upon imports, and the rich country mostly creates new products.

exports and imports in a 4-digit SITC or 6-digit NAICS code. Such categories, particularly the large ones, can be a collection of multiple "products" in the model. Though less sharp, the arrival of innovation on products also have implications on the change in exports and imports of export categories.

We mimic an export category in the data by randomly allocating products in the model to a category. We assume that a constant fraction of new products κ_c are allocated to new categories and the remainder to existing categories. The creation of new categories combined with exit of products in existing categories due to obsolescence generates a stationary distribution of products per category. Differences in size across export categories come from heterogeneity in the number of products in the category and in the average quality of products in the category. We pick κ_c to match the size distribution of exports in 4-digit SITC categories in the U.S.

Figure 6: Exit rate by decile of export category



Note: Average exit rate of an export *category* by deciles of the export category in home country in the simulated polar model where the home country mostly innovates on its products and the foreign country mostly innovates on its imports. See notes to Figure 1 and text for more details on this polar model.

Figure 6 shows the simulated average exit rate of an export category by size deciles of the export category. This is for the polar model in Figure 1 where the home country innovates on its products and the foreign country innovates on its imports. The home country loses an export category (i) when it loses all the products in that category from obsolescence or (ii) when the foreign country innovates upon and replaces all of the home country's exported products in that category.[12] The probability an export category exits therefore depends on the

[12] When a multi-product category exits due to a combination of obsolescence and foreign

number of products in the category and on the average quality of these products, along with innovation rates at home and abroad. In particular, categories with fewer products are more likely to exit either due to obsolescence or foreign innovations, while categories with low average product quality are likely to exit due to obsolescence.

Figure 6 shows that exit from innovation by foreign firms is roughly constant for the bottom three deciles of export categories and falls with size thereafter. This suggests that the number of products per category is likely to be small for exports categories in the bottom three deciles. In the data then when we measure the distribution of positive export growth, we will focus on the bottom quartile of export categories as the smaller export categories are likely to consist of a small number of products. Focusing on categories with only few products allows us to attain sharp identification; export and import growth of categories with large products are not very responsive to innovation rates because different types of innovations are likely to hit these large categories simultaneously, obscuring the effects of each force.

Figure 6 also shows that exit from obsolesence is concentrated in the bottom decile of export categories. This is not a problem for the sample of categories with *positive* export growth but it makes inference more difficult for the sample of *import* categories with negative growth (foreign exports); we would like to infer from the amount of negative import growth the extent of innovations on imports (δ), not the extent of obsolescence. To remove the effect of obsolescence, we will focus on the bottom 25 to 75 percentile of a country's imports when calculating the distribution of negative import growth.

In the model we mimic product categories in the data by assuming that a fraction κ_c of each country's new products are assigned to new product categories and the remainder $1 - \kappa_c$ are randomly assigned to existing product categories.

innovations, we weight the exit by the number of products in the category that exited due to each cause. For example, if a country loses a two-product category because one product exits due to obsolescence and another due to foreign innovations, we attribute 1/2 of the category exit to obsolescence and 1/2 to foreign innovations.

The parameter κ_c thus determines the distribution of the number of products per category across export categories.

4. Data and Estimation

The key data we use is the cross-category distribution of positive export growth and negative import growth of a country.[13] We use Feenstra et al. (2005)'s data on bilateral trade at the 4-digit SITC level. We restrict to manufacturing industries and 20 countries (we group the EU countries, including the United Kingdom, into one country) that collectively account for 95% of world exports. We work with non-overlapping five year periods from 1991 through 2016. In each five year period and country, we normalize the growth rate of total exports and total imports to zero. After we impose this normalization, we measure the normalized growth rate of an export (import) category as the change in exports (import) divided by the average of exports (imports) in the category at the beginning and at the end of the five year period. The growth rate of a new export (import) category is thus 2; the growth rate of an export (import) category that exits is -2.

We measure the distribution of positive export growth for the bottom quartile of export categories in each country at the beginning of each five year period. The specific moment we use is the share of export growth where the growth rate is > 1. For the distribution of negative import growth, we restrict the import categories to those between the 25 and 75th percentiles of imports (also for each five year period and the beginning of each five year period). The specific moment we use is the share of negative import growth where the growth rate is < -1.

The additional data moments we use are TFP, employment, and the trade share. The trade share is the share of exports in manufacturing GDP (from the World Development Indicators). We measure TFP from the Penn World Database and manufacturing employment as the residual of manufacturing GDP (from the

[13]Our strategy is akin to that in Garcia-Macia, Hsieh and Klenow (2019), who estimate innovation rates in a closed-economy growth model using the distribution of employment growth across firms within the U.S.

Table 3: Empirical Moments

	U.S.	Other Rich	China	Other Poor	World
TFP	1	0.751	0.441	0.507	0.678
Trade Share	18.4%	24.1%	16.2%	26.4%	20.9%
Export Growth > 1	55.2%	64.5%	63.9%	71.4%	63.3%
Import Growth < -1	5.4%	7.7%	15.0%	16.5%	10.5%

Note: TFP is manufacturing TFP relative to the US. Export growth is the share of export categories with a growth rate > 1 among exports with positive growth calculated among exports in the bottom quartile. Import decline is the share of import categories with a growth rate < 1 among imports with negative growth calculated among imports among the bottom 25-75 percentile. Growth rate defined as change in exports (imports) divided by the average of exports (imports) of the category at the beginning and end of each five year period, averaged over successive five-year periods from 1991 through 2016 for each country in the 4-digit SITC trade data. Growth of total imports and exports normalized to zero for each country and five year period. Other Rich, Other Poor, and World is the GDP weighted average of the countries in our sample.

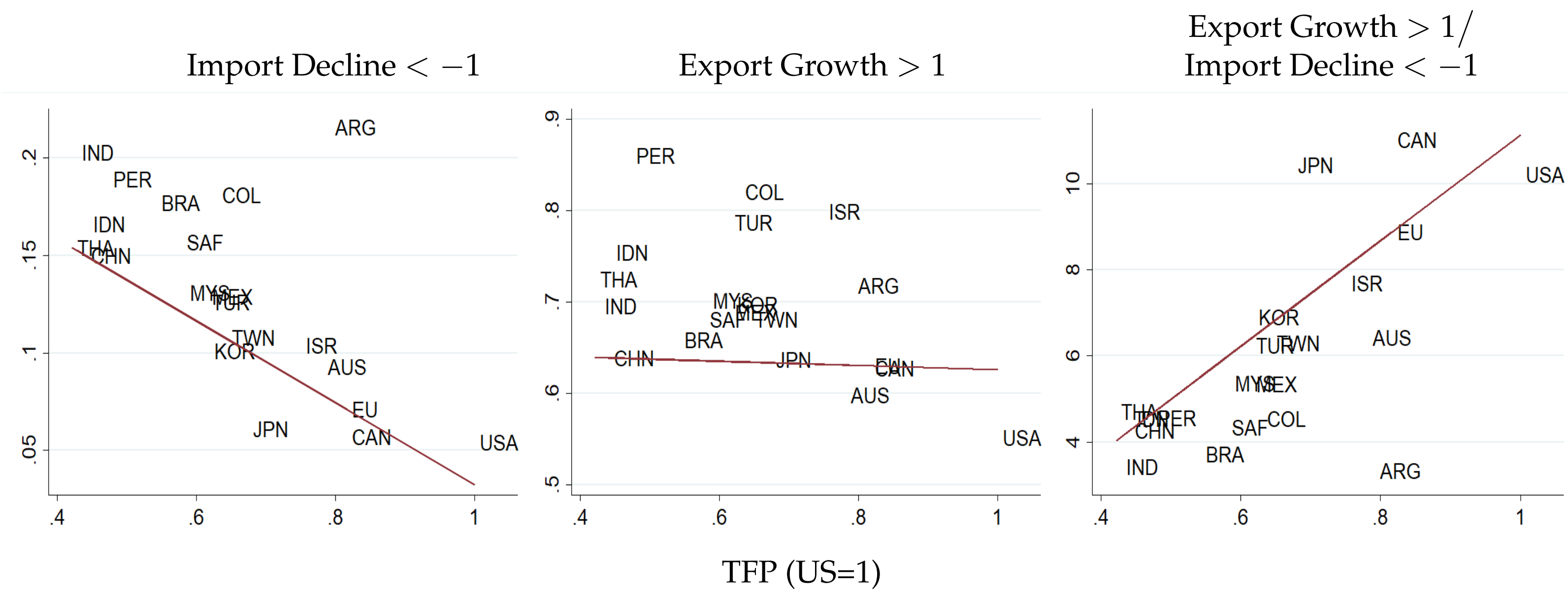
World Development Indicators) after accounting for the effect of TFP. We assume employment grows at a common rate of 1% per year in all countries.

Table 3 summarizes TFP, trade share, the share of small positive export growth, and the share of large negative import decline for the US, other rich countries, China, and other poor countries.[14] The first two panels in Figure 7 plots the two moments of exports and imports we use, namely the share of large import decline (left panel) and the share of the share of small export growth (middle panel), against the country's TFP. The left panel shows that large import declines, which in the model is driven by innovation on imports, are more frequent in poor countries compared to rich countries. The middle panel shows that the share of small increases in exports, which in the model reflects the relative importance of innovation on domestic products versus innovation on imports and new product

[14]Rich countries are the ten countries with the highest TFP in our sample; poor countries are the ten countries with the lowest TFP in our sample. Table B1 in the Appendix shows the data moments for all 20 countries.

creation, is larger in rich countries versus poorer countries. The right panel shows the *residual* of large export increases, namely the ratio of the share of large export increases to the share of large import declines. So the right panel suggests that the residual of large increases in exports, which in the model reflects innovation via the creation of new products, is larger in high TFP countries compared to poorer ones.

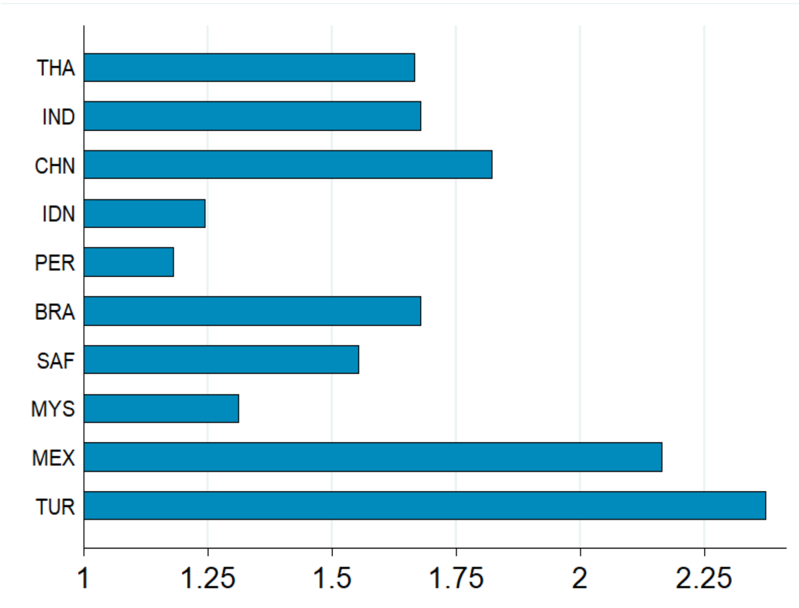
Figure 7: Data: Import Decline and Export Growth vs. TFP



Note: Figure plots the share of import decline with a growth rate < -1 (left panel), the share of positive exports with a growth rate > 1 (middle panel), and the ratio of the share of positive exports with a growth rate > 1 to the share of import decline with a growth rate < -1 (right panel). Growth rate defined as change in exports of exports divided by the average of exports of the category at the beginning and end of each five year period. Export growth and import decline is average over successive five-year periods from 1991 through 2016 for each country in the 4-digit SITC trade data. Growth rate of total exports and imports normalized to zero for each country and five year period. Red solid line is fitted value from an OLS regression weighted by GDP.

For the poor countries, we also calculate the ratio of the share of large import decline (growth rate < -1) for their imports from other poor countries to the share of large import declines for their imports from the rich countries, shown in Figure 8. This ratio averages 1.80 for the poor countries in our sample. So for poor countries, large declines in imports from other poor countries occur with greater frequency compared to imports from rich countries. In the model, this suggests that a poor country finds it more difficult to replace an import from a rich country compared to an import from a poor country.

Figure 8: Imports from poor vs. rich countries with strongly negative growth



Note: Figure plots the share of import decline < -1 of imports from poor countries relative to the share of large import decline for imports from rich countries. Countries are ordered by increasing TFP.

The model consists of four parameters for each country (κ, δ, λ, and τ) and four parameters (f, θ, κ_c, ρ, and σ) that are the same in all countries. We assume the parameter α that governs spillovers of imports from rich countries to poor countries is the same for the bottom five poor countries, and for the next five poor countries.[15] So in total the model has 87 parameters.[16] We assume $\sigma = 4$ and pick f so that the average number of products per country is between 2,500-

[15]We assume $\alpha = 1$ for the rich countries.

[16]4 parameters common to all countries, 5 country-specific parameters for each of the 20 countries, 1 parameter common to the bottom five poor countries, and 1 parameter common to the next five poor countries.

5,000.[17] For the remaining parameters, the inference works as follows.[18] In the first step, we assume a value for the shape parameter of the distribution of the innovation step size θ. Taking as given θ and imposing trade balance for each country, the data on relative TFP, relative employment, and the trade share collectively identifies each country's overall innovation rate (from all three sources of innovation) relative to the U.S. and the trade cost τ. Then, conditional on τ and relative TFP, the ratio of large import declines of poor countries for their imports from other poor countries to their imports from rich countries and the share of large import declines (from imports from all sources) collectively pins down the spillover parameter for poor countries α and the innovation rate on imports δ. And conditional on α, δ, relative TFP, τ, and each country's overall innovation rate, the share of small changes in export growth from the data identifies the share of innovation that takes the form of quality improvement on domestic products λ versus the combination of innovation on imports δ and the creation of new varieties κ. The aggregate growth rate (assumed to be the same for all countries) and the share of U.S. exports that grow then collectively pin down the quality step size of innovation (and thus the shape parameter of the distribution of the step size of innovation θ) and the overall U.S. innovation rate.[19] Finally, we choose κ_c to match the exit rate of an export category in the bottom quartile of exports over five years.[20]

[17]The number of products does not affect the distribution of quality, and hence the moments in expectation. It does affect the granularity of the model, however, and hence the distribution of export and import growth rates.

[18]Appendix Section A provides more details on the estimation procedure.

[19]We use a growth rate of 15.9% per five-year period and 45.4% for the share of U.S. exports that grow over a five year period (based on the U.S. 4-digit export data).

[20]The average exit rate of an export category in the bottom quartile over five years is 19% for the 20 countries in our 4-digit SITC trade data.

5. Parameter Estimates

Table 4 presents the arrival rates of innovations and trade cost in the US, the EU, China, and the rest of the world inferred from the data moments.[21] The top panel shows the arrival rates of innovation, the middle panel shows the probability of *successful* innovation as the product of the innovation arrival rate and the probability that the innovator also takes over the product, and the bottom panel shows the trade cost τ. The imitation parameter α governs the scale parameter of innovation on imports by a poor countries. We estimate parameter as 0.531 for the poorest five countries and 0.449 for the next five poor countries.

We take three messages from the table. First, the creation rate of new products is higher in the U.S. compared to other countries. The arrival rate of new products is notably lower in China at 0.8%. Second, the probabilities of a successful innovation on imported products are *lower* in the U.S. compared to other countries. The arrival rate of successful innovation on imported products is only 0.2% in the U.S. and averages 2.1% in the world. Third the values of the imitation parameter α implies that the scale parameter of innovation by poor countries on imports from rich countries is quite low.

Figure 9 plots the arrival rates of innovation versus the country's TFP (top panel) and employment (bottom panel). Compared to lower TFP countries, high TFP countries innovate on their own products more frequently. Compared to smaller countries, large countries innovate on domestic products a little more frequently.

[21]The full set of parameter estimates is found in the Appendix Tables B4. Figure B1 in the Appendix shows the fit of the model implied by the innovation rates and trade costs in Table 4. The figure plots TFP, the trade share, the share of small positive export growth, and the share of large import declines implied by the parameter estimates in Table 4 against the data for the same variables for our 20 countries.

Table 4: Estimates of Innovation and Trade Cost

	U.S.	Other Rich	China	Other Poor	World
Innovation Rate					
Domestic Products λ	93.8%	80.1%	2.0%	51.0%	56.0%
Imported Products δ	3.6%	7.1%	8.0%	6.7%	6.6%
Imitation Parameter α	1	1	0.531	0.492	.
New Products κ	77.6%	2.3%	0.8%	22.0%	27.0%
Successful Innovation Rate					
Domestic Products	54.0%	26.2%	0.8%	14.5%	22.7%
Imported Products	0.4%	2.5%	4.3%	2.1%	2.6%
New Products	30.0%	6.1%	0.3%	5.5%	8.4%
Trade Cost τ	1.39	1.29	2.64	1.91	1.78

Note: Top panel shows the arrival rates of innovation and the scale parameter of the innovation on imported products. Middle panel shows the product of the arrival rates of innovation and the probability that the innovator also becomes the producer. Bottom panel shows the gross trade cost. Other Rich, Other Poor, and World are GDP-weighted averages.

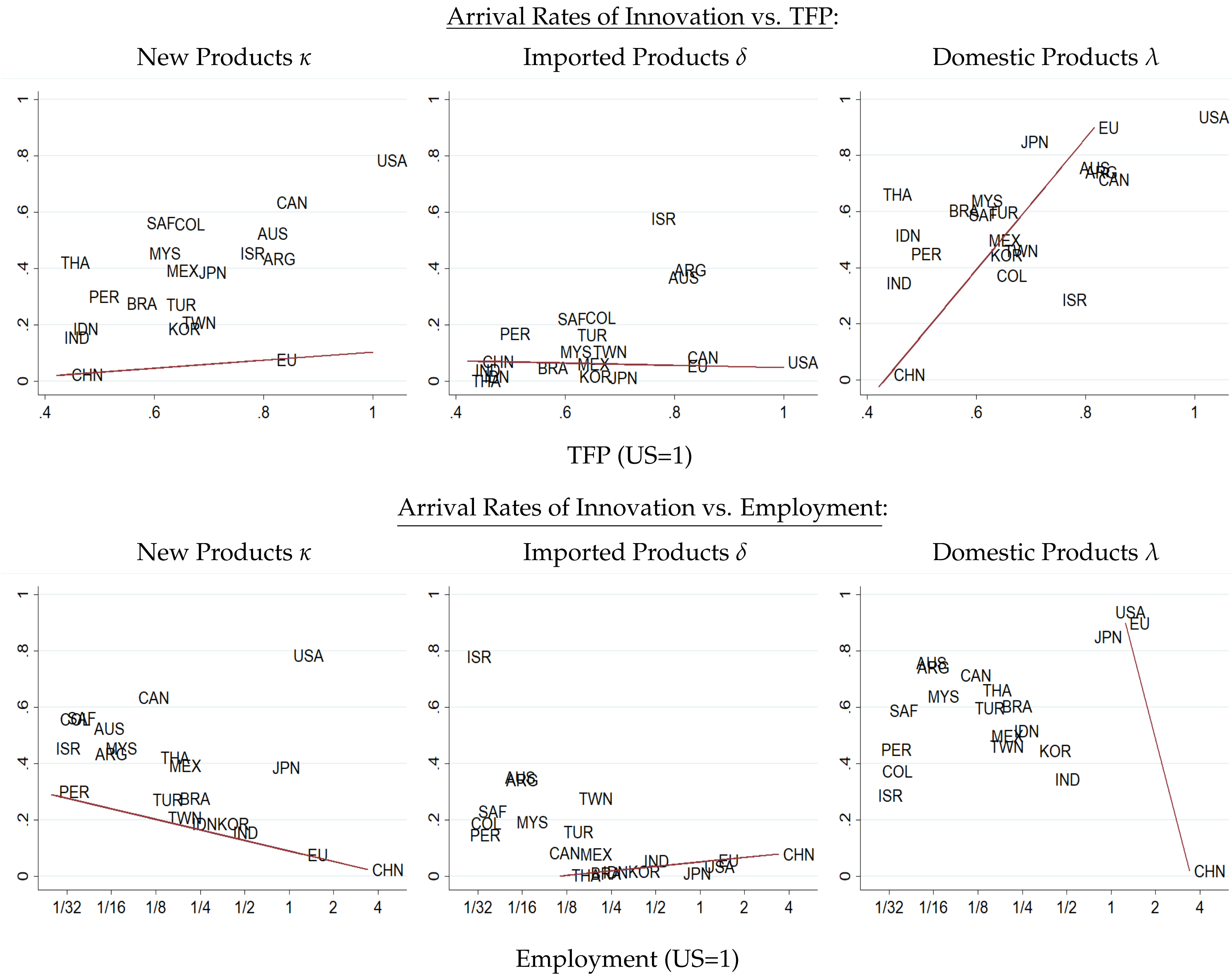
6. TFP, Growth, Trade, and the Product Life-Cycle

In the model, each country is summarized by the three innovation arrival rates $(\delta, \lambda, \kappa)$ and the trade cost τ. In this section, we show the implication of these parameters we estimate for the TFP gaps, sources of growth, the share of Romerian versus Ricardian trade of each country, and the global product life-cycle.

6.1 TFP Accounting

We start with the TFP accounting exercise. Specifically, Table 5 shows the share of the TFP gap of each country relative to the U.S. that is "explained" by the

Figure 9: Arrival Rates of Innovation



Note: Figure shows the arrival rates of new products, innovation on imported products, and innovation on domestic products against TFP (top panel) and total labor supply (bottom panel). Solid red line is the OLS regression line weighted by GDP.

difference in λ, δ, and κ of each country relative to the US.[22] The shares do not add up to 100% because differences in labor supply and trade costs, as well as the non-linearities in the model, also affect TFP gaps.

Table 5: TFP Gap relative to U.S. explained by λ, δ and κ

	Other Rich	China	Other Poor	World
Innovation on Domestic Products λ	10.8%	27.3%	17.1%	17.9%
Innovation on Imported Products δ	-5.3%	-14.0%	2.1%	-7.3%
Creation of New Products κ	80.7%	61.1%	43.0%	67.8%

Note: Table shows share of the TFP gap between a country and the U.S. due to the gap in λ (row 1), δ (row 2), and κ (row 3) between each country and the US. Other rich, other poor, and world are GDP-weighted averages.

We make three observations from the table. First, new variety creation – the Romerian force – is the most important force driving the TFP gap of most countries relative to the US. The difference in κ explains 81% and 61% of the TFP gaps between other rich countries and the U.S. and between China and the US, respectively. For the average country in the world, new variety creation accounts for 68% of the TFP gap relative to the US. Second, innovations on imported products – the Ricardian force – does not explain lower TFP relative to the US. The difference in the arrival rate of innovation on imported products between other rich countries and the U.S. *lowers* the TFP gap vis-a-vis the US. For the average country, innovation on imports explains -7% of the TFP gap with the US. Third, the innovation rate on domestic products only explains a small share of TFP gap with the US. The share of the TFP gap with the U.S. for the average country is -18%.

[22] We use the standard approach of chaining. For example, in row 1 we compute the gap in TFP between the country and the U.S. by changing λ of the country to that of the U.S. holding fixed the other forcing variables. Then we compute the change in the TFP gap by changing λ in the U.S. to that of the country in question, again holding the other variables fixed. We take the average of the two estimates of the change in the TFP gap from changing λ, and show the ratio of this number to the TFP gap observed in the data.

6.2 Growth Accounting

In the model all countries grow at the same rate in the steady state but they differ in the sources behind their growth. In this section, we show the contribution of quality growth versus new varieties and the contribution of domestic versus foreign innovation to each country's growth.

The top panel of Table 6 shows the growth contribution of domestic versus foreign innovation given by equation (6). About 26% of U.S. growth comes from innovation activities of foreign companies while the share of growth from foreign innovation is much higher in other countries. The contribution of foreign innovation to growth is 65% in other rich countries, 22% in China, and 60% in other poor countries. So the U.S. is an exception in that U.S. growth mostly comes from domestic innovation.

Table 6: Growth Accounting

	U.S.	Other Rich	China	Other Poor	World
Domestic vs. Foreign Innovation					
Domestic Innovation	74.2%	35.4%	78.1%	39.5%	56.1%
Foreign Innovation	25.8%	64.6%	21.9%	60.4%	43.9%
Quality Growth vs. New Products					
Quality Growth	35.6%	48.1%	85.3%	53.6%	57.3%
New Products	64.4%	51.9%	14.7%	46.4%	42.7%

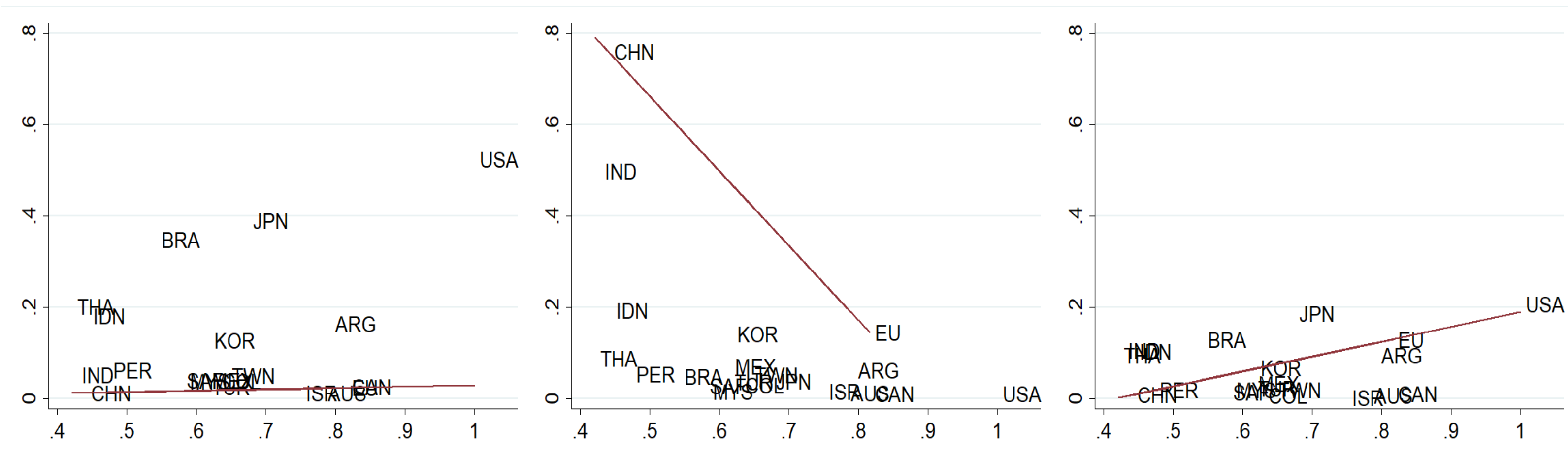
Note: Table shows the share of growth from domestic versus foreign innovation in the top panel following equation (5) and the share of growth from quality upgrading versus new products in the bottom panel following equation (6). Other rich, other poor, and world are GDP-weighted averages.

The bottom panel in Table 6 decomposes growth in each country into the contribution of quality upgrading versus new products following equation (5). About 64% of U.S. growth comes from the introduction of new products. The share of growth from new products is lower in other rich countries and China, at 52% and 15% respectively. While not as extreme as the share of growth from foreign versus domestic innovation, the share of growth from new products versus quality upgrading in the U.S. is also an outlier compared to other countries.

Figure 10: Share of Growth from Domestic Innovation

Share of Growth from:

New Products κ | Imported Products δ | Domestic Products λ

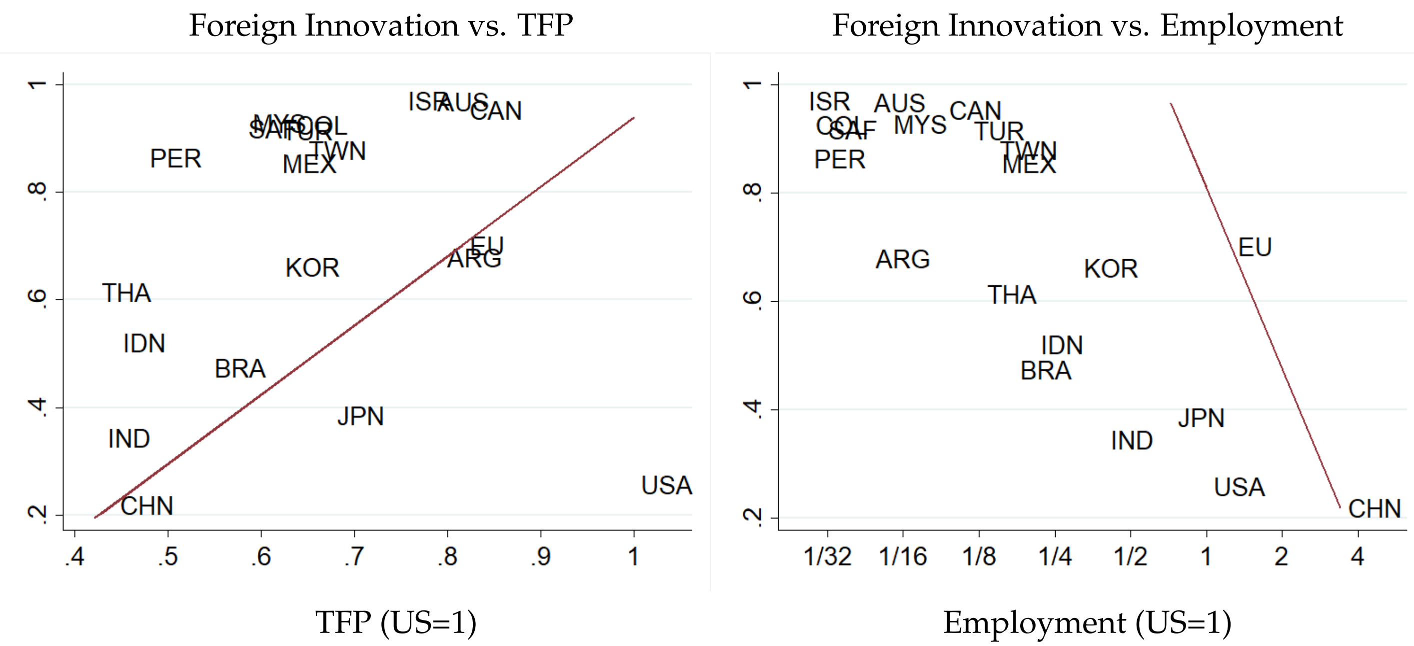


TFP (US=1)

Note: Figure shows the share of growth from creation of new domestic varieties (left panel), domestic innovation on imported products (middle panel), and domestic innovation on domestic products (right panel). Red solid line is OLS regression line weighted by the country's GDP.

Figure 10 further decomposes the growth contribution of domestic innovation into parts due to domestic innovation in the form of new products (left panel), quality improvements on imports (middle panel), and quality improvement on domestic products (right panel). We make three observations. First, creation of new products accounts for more than 50% of the U.S. growth and essentially zero of Chinese growth, but it is generally not the case that the share of growth from κ is higher in high TFP countries compared to low TFP countries. Second, the share of growth from innovations on imports tends to be higher for countries with lower TFPs. This is because the marginal cost of production falls sharply when a low wage country successfully innovates upon a product imported from a high wage country. Third, the share of growth from innovations on domestic products is positively correlated with the country's TFP.

Figure 11: Share of Growth from Foreign Innovation

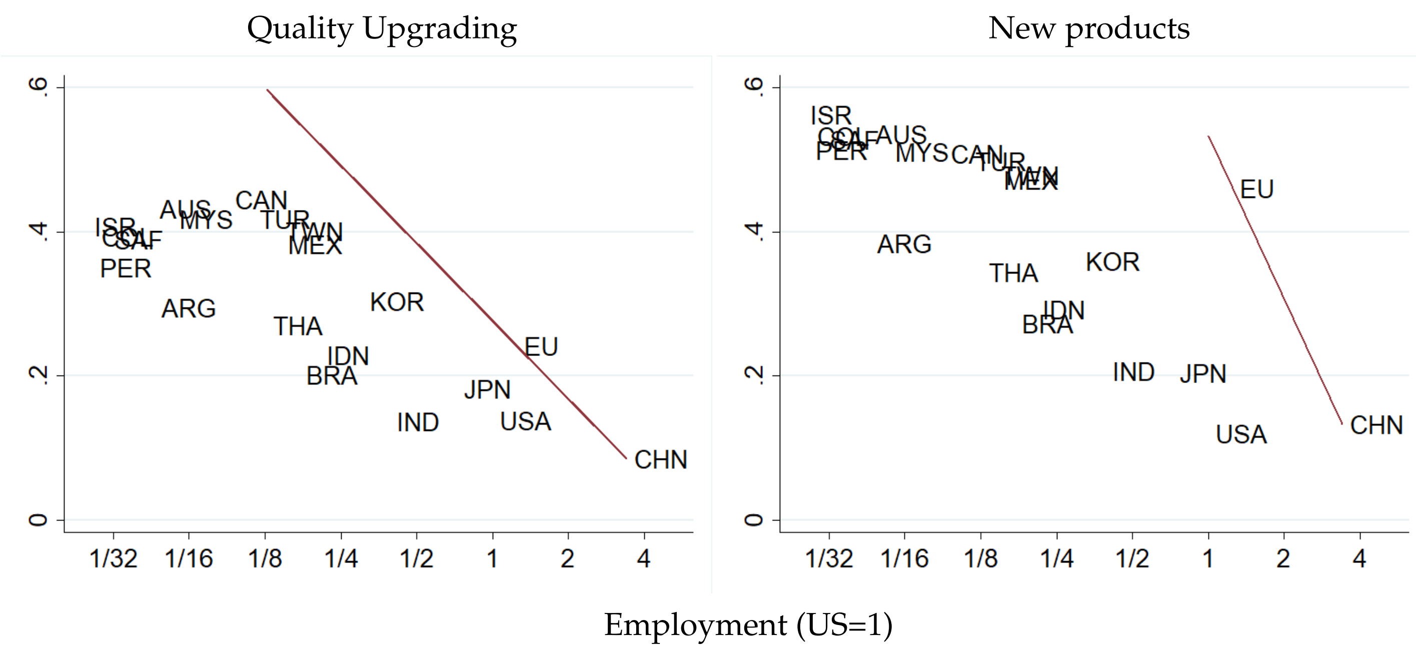


Note: Figure shows the contribution of foreign innovation as in equation (5) to a country's growth versus the country's TFP (left panel) and labor supply (right panel). Red solid line is OLS regression line weighted by the country's GDP.

Figure 11 plots the growth contribution from foreign innovation. The left panel shows that the contribution of foreign innovation is higher in richer countries, although the U.S. is an outlier. The right panel shows that smaller countries depend a lot more on foreign innovation compared to larger countries. One extreme are countries such as South Africa and Israel where more than 90% of aggregate growth comes from foreign innovation. The other extreme are the U.S. and China where foreign innovation only accounts for 20% of GDP growth.

As shown in equation (5), foreign innovation contributes to a country's growth by improving the quality of products currently sold in the country and by introducing new foreign products into the country's market. Figure 12 shows the growth contribution of these two sources of foreign innovation as a function of the country's labor force. The figure shows that the main reason foreign innovation matters more for smaller countries is because of new foreign products. In a typical small country such as South Africa and Israel, new foreign products are responsible for 50-60% of the country's growth. In the U.S. and China, new foreign products account for slightly over 10% of growth. The contribution of quality growth from foreign innovation on products the country already consumes is also higher in smaller countries.

Figure 12: Share of Growth from Foreign Innovation:
Quality Upgrading vs. New Products



Note: Figure shows the contribution of quality upgrading and introduction of new products as in equation (6) to a country's growth versus the country labor supply. Red solid line is OLS regression line weighted by the country's GDP.

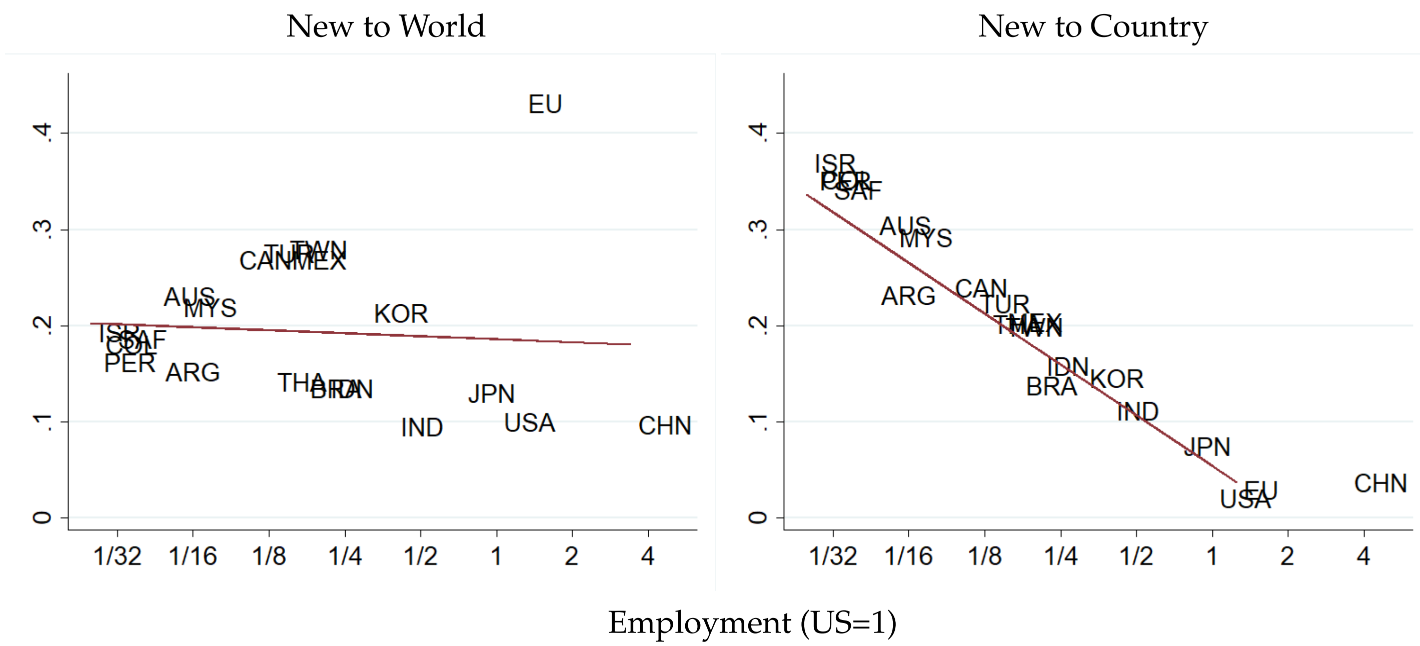
Figure 13 further decomposes the growth contribution of foreign new products into the contribution of foreign products that are new to the world (left panel) and foreign products that are new to the country but not to the world (right panel). The latter are products that were previously not sold in a country but that become available to the country's consumers when the product is improved upon by a country with a significantly lower wage than that of the incumbent country. This effect is large for a small country because the profits from selling to the small market often does not justify the fixed cost. As a result, many products, particularly products made by high wage countries, will not be sold in small markets until a low wage country innovates upon and takes over the product. Figure 13 shows that the higher contribution of new foreign products to growth in low TFP countries comes entirely from foreign products that are new only to the country but not the world, and not from new foreign products that are new to the world. In small markets such as a Israel and South Africa, the introduction of foreign products that are new to the local market but not new to the world accounts for 30-40% of aggregate growth.

The model predicts that entry of new imports will be more frequent in smaller countries. We in fact observe this pattern in the data. Figure 14 compares the empirical distributions of positive import growth for the U.S. and South Africa. As before, the import growth for a product category is defined as the change in imports of the product category divided by the average of the category's imports prior and after innovation. Notice that the share of import growth equal to 2 is about three times higher in South Africa compared to the US. Remember that we did not target any moments on (positive) import growth when calibrating the model.

6.3 Trade Accounting: Ricardian versus Romerian Trade

The innovation parameters also determine the share of Romerian versus Ricardian products in a country's exports. We remind the reader that we define a Romerian product as one where only one country has the blueprint, and a Ricardian product as one where more than one country has the blueprint for the

Figure 13: Share of Growth from Foreign New Products



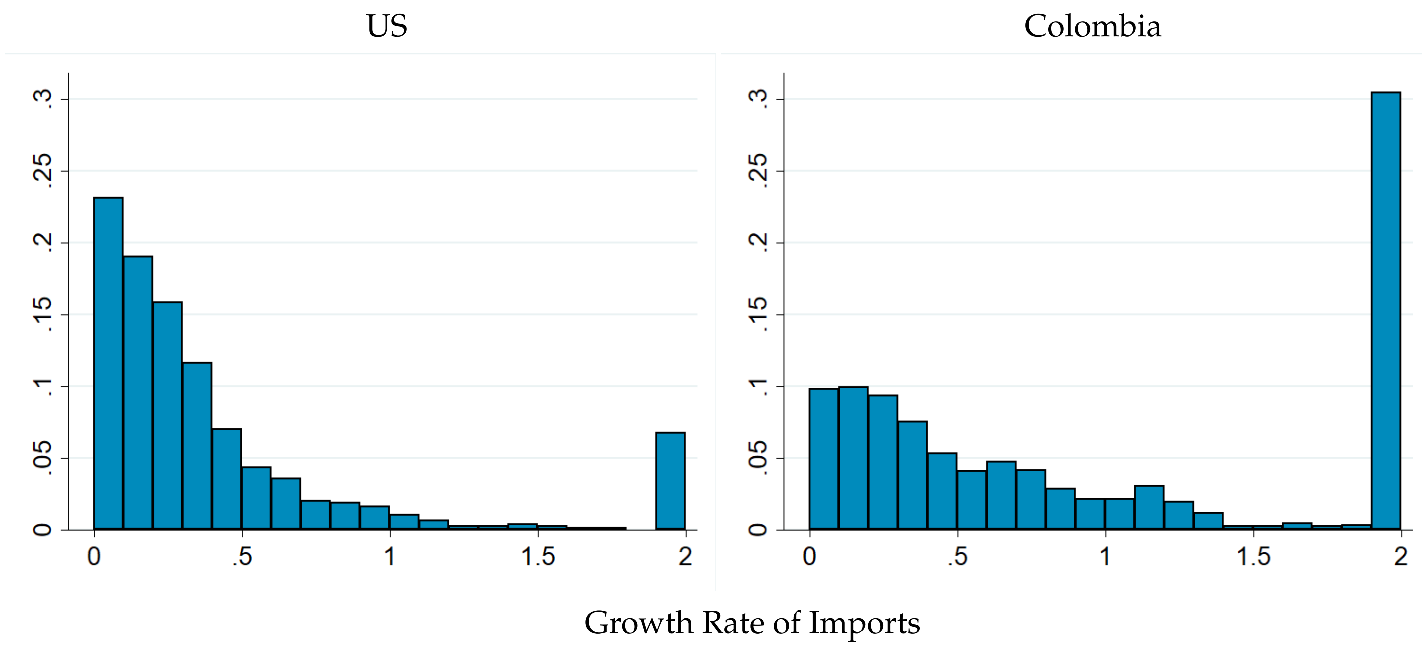
Note: Figure shows the contribution of foreign new products that are also new to the world (left panel) and foreign new products that are only new to the importing country but not to the world (right panel) to a country's growth versus the country labor supply. Red solid line is OLS regression line.

product.[23] Table 7 shows the export shares of Romerian products in a country's exports, where the rows are the origin countries and the columns are the destination countries. The last column (World) thus shows the Romerian share of each country's total exports.

We highlight the following findings from Table 7. First, U.S. exports are predominatly Romerian while Chinese exports are mainly Ricardian. Second, the U.S. and China are outliers in that exports from other rich countries are primarily Ricardian and about 33% of exports from other poor countries are Romerian. Third, there is some evidence that countries sell more Romerian goods to richer

[23]When an innovator in a country attempts to innovate upon a Romerian product produced by another country, but fails to take over the product even in the domestic market due to the wage differences, we consider the blueprint to be lost in the country where the innovator is located. That is, the product remains Romerian in this case.

Figure 14: Empirical Distribution of Positive Import Growth



Note: Figure shows the distribution of positive import growth averaged over non-overlapping five year periods from 1991 to 2016 in Colombia and the U.S. in the 4-digit trade data. Growth rate defined as change in imports of the import category divided by the average of imports of the category at the beginning and end of the five year period. Total import growth normalized to zero for each country and each five-year period.

countries compared to poorer ones.

Figure 15 decomposes the variation in the share of Romerian versus Ricardian products across countries into the net growth of Romerian exports (top panel) and Ricardian exports (bottom panel). A country gains a Romerian export when it creates a new product, which depends on the magnitude of κ. A country gains a Ricardian export when it improves upon and replaces its imports, which is a function of the country's δ and the scale parameter of innovation on imports α.

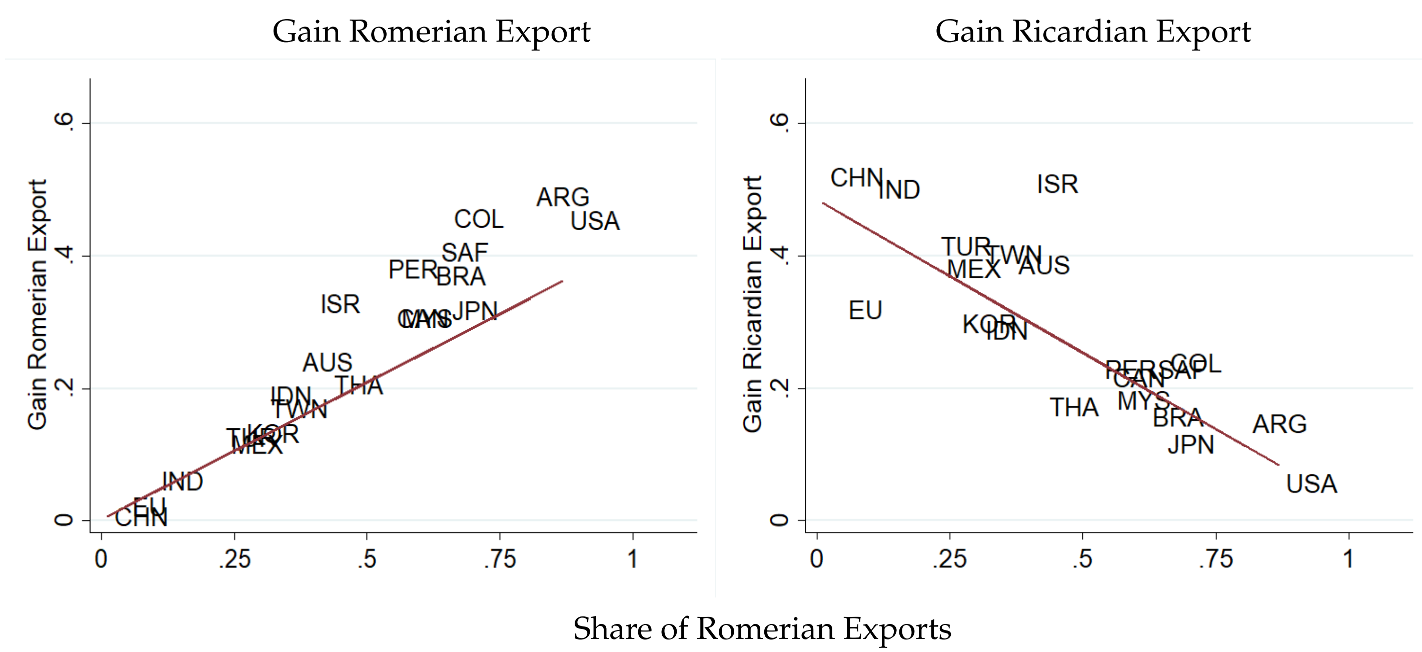
Figure 15 shows the arrival rate of Romerian products (left panel) and Ricardian products (right panel) as a function of the share of Romerian products in the country's exports in steady-state. The left panel shows that cross-country differences in the rate at which countries gain a Romerian product is positively

Table 7: Export Share of Romerian Products

	U.S.	Other Rich	China	Other Poor	World
U.S.	.	90.1%	86.1%	71.3%	86.7%
Other Rich	19.4%	38.5%	22.6%	12.8%	22.3%
China	1.7%	1.4%	.	0.7%	1.1%
Other Poor	37.2%	39.1%	39.4%	22.1%	33.1%
World	22.2%	46.8%	36.4%	17.7%	32.3%

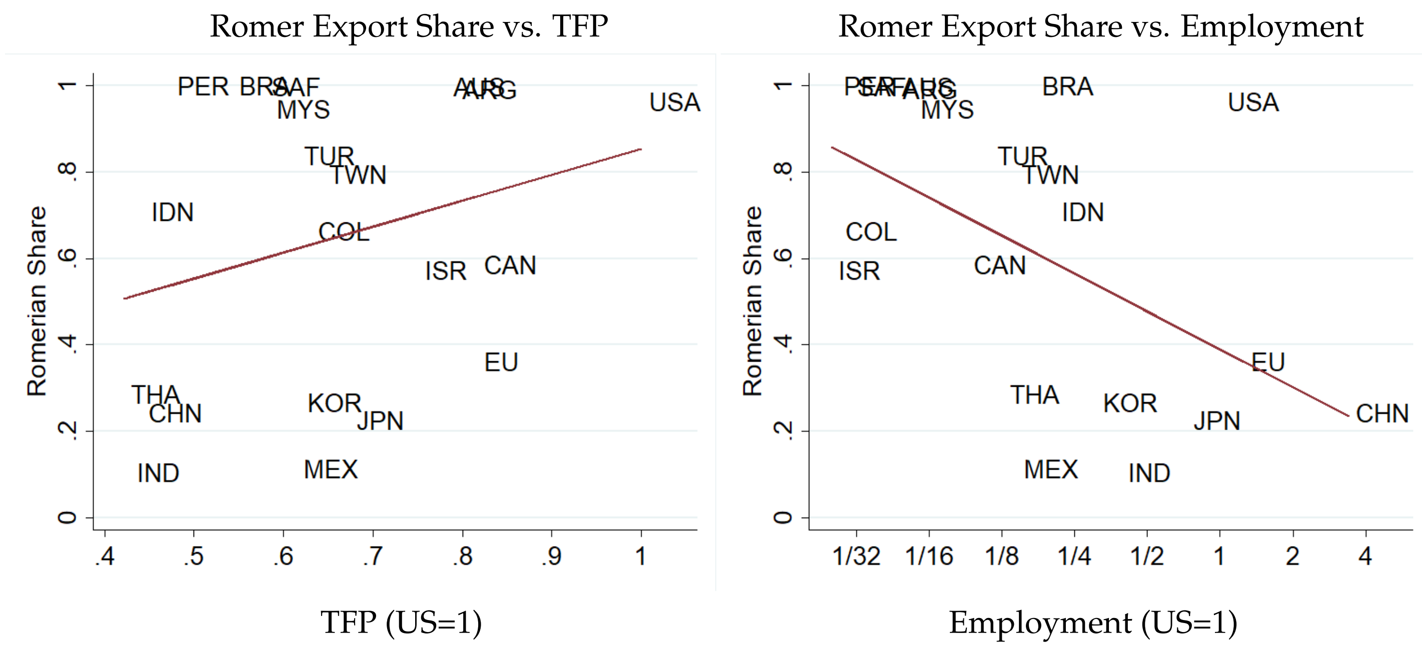
Note: Table shows the share of Romerian products in a country's exports. Origin countries are in the rows and destination countries are in the columns. Other rich, other poor, and world are GDP weighted averages.

Figure 15: Decomposing Share of Romerian Trade



Note: Figure shows the probability (per exported product of a country) that a country gains a Romerian product (left panel) or a Ricardian product (right panel). Red solid line is OLS regression line weighted by the country's GDP.

Figure 16: Romerian Share of Exports vs. TFP and Employment



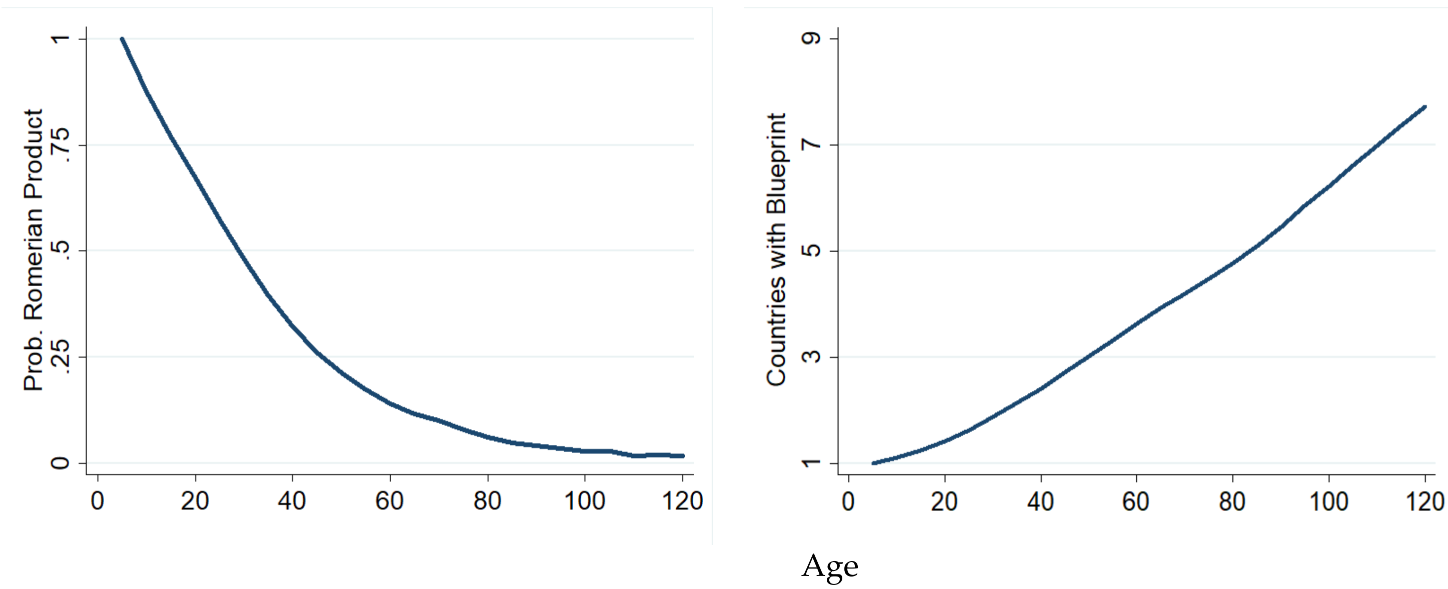
Note: Figure plots the share of Romerian products in a country's exports versus the country's TFP (left panel) or Employment (right panel). Red solid line is OLS regression line weighted by the country's GDP.

correlated with the Romerian share of exports, with India and China at one extreme with an arrival rate of essentially zero and the U.S. at the other extreme with an arrival rate of 45%. The right panel shows that the arrival rate of *Ricardian* exports is negatively correlated with the Romerian share. The arrival rate of Ricardian exports ranges from 50% for India and China to about 5% for the US.

Figure 16 plots the Romerian share of exports of a country versus the country's TFP (left panel) and employment (right panel). The share of Romerian goods in a country's exports is typically higher in rich countries compared to poorer countries. The share of Romerian goods in India and China's exports are 10% and about 20%, respectively, while the share in the U.S. is about 90%. Still there are many exceptions as there are many poor countries (such as Peru and Brazil) that primarily export Romerian goods, and some rich countries (such as the EU) whose exports are primarily Ricardian. The right panel shows that the Romerian share of exports is typically lower in larger countries, with the U.S. being a notable exception.

6.4 Product Life-Cycle

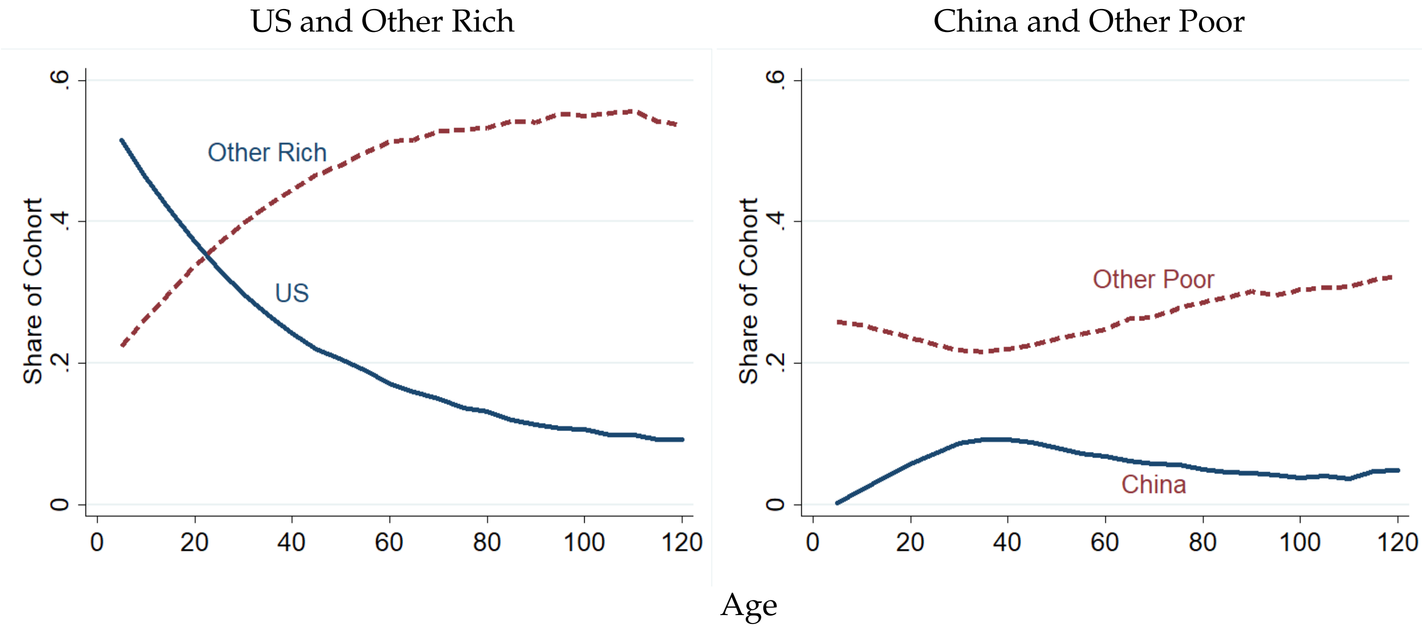
Figure 17: Products become "More" Ricardian



Note: Figure shows the share of Romerian product (left panel) and the average number of countries that has the blueprint for a product (right panel) among all existing products of a given cohort of products in the world as a function of the cohort's age.

In this section, we draw out the implication of the innovation parameters we estimated for the product life-cycle. First, new products are by definition Romerian but they gradually change into Ricardian products as they get improved upon by innovators in other countries. Figure 17 shows the transition from Romerian to Ricardian products over a product's life-cycle. Specifically, the left panel shows the share of a given cohort of products that are Romerian as a function of the cohort's age. The half-life of a Romerian product is about 30 years as other countries innovate and turn the Romerian product into a Ricardian

Figure 18: Reallocation of Products Across Countries



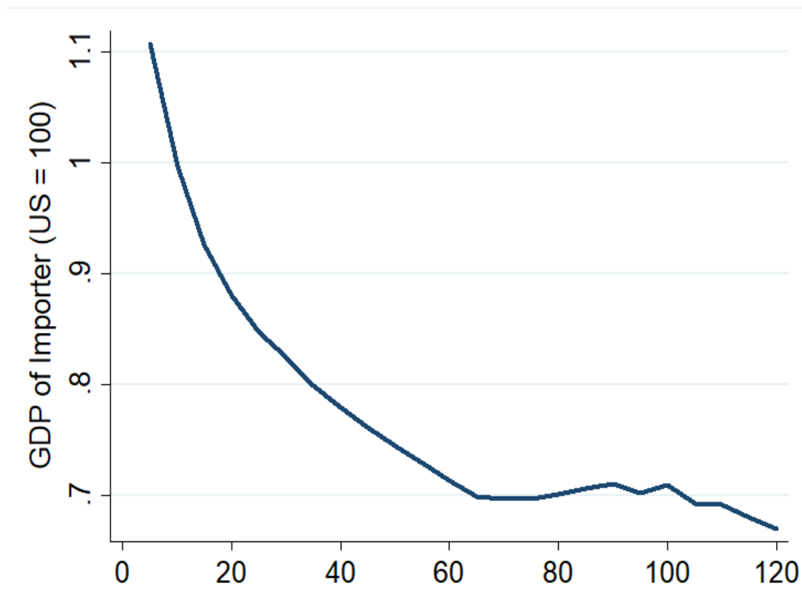
Note: Figure shows the share of products that belong to the US, China, other rich countries, and other poor countries among all existing products of a given cohort of products in the world as a function of the cohort's age.

product. The right panel shows that the average number of countries that have the blueprint of an average product as a function of the product's age. This figure shows how technology diffuses across countries over time, as countries innovate upon their imports. We assume that markups are constant in our model, but in a model where the number of potential producers matters for the markup, the diffusion of products across countries could have important implications for the markup.

The next figure shows how products move across countries as they age. The left panel in Figure 18 shows the share of a given cohort of products that belong to the U.S. and other rich countries as a function of age. About 50% of all new products are from the US, and about 20% of new products are from the other countries. Over time, the U.S. loses its new products to innovators in the other rich countries: the half-life of a Romerian American product is about 30 years. On the other hand, the share of products produced by other rich countries doubles over the first 30 years of a product's life.

The right panel in Figure 18 shows the evolution of the share of the cohort belonging to China and other poor countries. The figure shows that the share of Chinese producers rises, and the share of other poor countries falls over the first 30 years of the product's life. Still, the reallocation of products over the life-cycle of a product is primarily from the U.S. to other rich countries, and not from rich countries to poor countries.

Figure 19: Product Life-Cycle: Size of Importers



Age

Note: Figure plots the GDP (relative to the US) of a country that imports a product as a function of the product's age.

Our last figure shows the life-cycle of an exported product in terms of the size of the country the product is exported to. Remember the evidence from Figure 13 that an important source of growth in small countries comes from new imports that are not new to the world but new to the importing country. Figure 19 shows the average GDP of an imported product (relative to U.S. GDP) as a function of the age of the product. New products as only sold in larger markets where the profits from selling in the market covers in the fixed cost. The figure shows that over time, as the product is improved upon by other firms, the product is exported to smaller markets where the producct was previously not sold.

7. Conclusion

We endeavored to answer the following questions: How much of existing trade is Romerian (reflecting differentiated varieties) versus Ricardian (reflecting differing quality levels of the same varieties)? Is there a global product cycle whereby new varieties are created in rich countries and later migrate to developing countries? How much do differentiated varieties versus quality levels contribute to TFP differences across countries? How much growth, on average, comes from new variety creation versus quality improvements? How much growth comes from home innovations versus innovations abroad?

We simulated a 20-country model of trade and growth, and inferred the arrival rates of new varieties and creative destruction to fit observed dynamics of export and import growth in each country. Our parameter estimates led us to five tentative answers to the questions we posed:

First, trade flows reflect Ricardian (70%) quality differences more than Romerian (30%) product differentiation. Second, the U.S. disproportionately creates new products and other rich countries disproportionately creatively destroy them. Third and related, TFP gaps relative to the U.S. reflect differences in new variety creation rather than in average qualities. Fourth, about 50% of growth comes from innovation on imports, and 44% from from new varieties where the latter includes products that are new to a country but not to the world. Fifth, a little less than one-half (44%) of growth comes from innovations abroad, though less for the U.S. (26%) and more for small countries (80% to 90%).

We hasten to add several caveats to our analysis. For one, our inference was indirect and could usefully be supplemented by detailed information on products produced by individual countries. For another, we set aside the modeling of endogenous innovation. This means we are silent on important questions such as how trade affects the incentive to innovate, and how trade policy affects growth, TFP differences, and welfare.

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Online Appendix

A. Estimation Procedure

1. Fix σ to 4 and set f such that the average number of products per country is between $2,500$ and $3,000$.

2. Set the initial distribution of qualities and initial random assignment of varieties to categories and specify the vector of model parameters (λ_j, δ_j, κ_j, τ, θ).

3. Solve for the [initial] equilibrium relative wages and TFPs.

   (a) Specify the initial guess for the vector of wages and TFPs.

   (b) Based on the guess, determine the trade flows.

   (c) Compute the TFPs of each country, the relative wages that would balance the trade of each country, and the distance between the guessed and solved wages and TFPs.

   (d) Update the guess and repeat (b) and (c) until the guess and solution become close.

4. Repeat step 3 for several years until the model attains stationarity while computing period specific moments in every iteration.

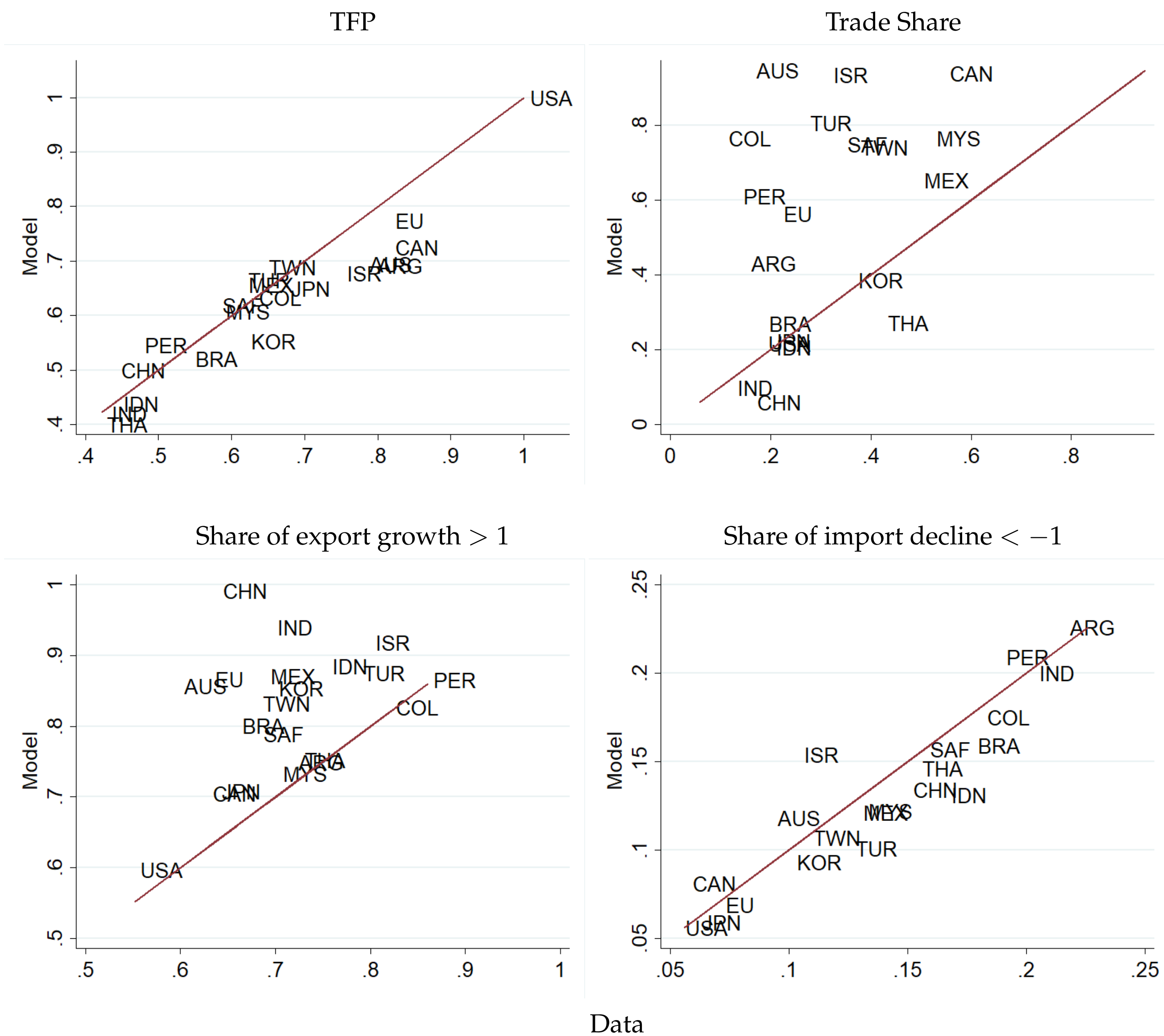
   (a) As determined by κ_c, randomly assign new varieties that are introduced in each period either to new categories at the rate of one product per category or to existing categories that are produced in the country.

5. Compute moments including product cycles, trade flows of Romerian products, and growth decomposition, along with the objective function.

6. Run the estimation 100 times with different seeds and take the averages of the parameters and computed moments of the five runs that best fit the empirical moments.

B. Additional Figures and Tables

Figure B1: Model vs. Data



Note: Figure shows the TFP, trade share, share of small export growth, and share of large import declines predicted by the model on the y-axis and in the data on the x-axis.

Table B1: Country Specific Empirical Moments

	TFP (US=1)	Export Growth > 1	Import Decline < −1	Import Decline Poor/Rich	Trade Share	Relative GDP
US	1	55.2%	5.4%		18.4%	1
China	0.441	63.9%	15%	1.825	16.2%	1.504
EU	0.816	63.0%	7.1%		21.5%	1.021
Japan	0.674	63.7%	6.1%		19.2%	0.487
India	0.428	69.6%	20.3%	1.682	12.2%	0.166
Korea	0.618	69.7%	10.1%		36.4%	0.189
Indonesia	0.444	75.4%	16.6%	1.247	20%	0.091
Brazil	0.542	65.9%	17.7%	1.682	18.5%	0.092
Mexico	0.615	68.9%	12.9%	2.167	49.5%	0.088
Taiwan	0.644	68.1%	10.8%		36.9%	0.091
Thailand	0.422	72.5%	15.4%	1.688	42.4%	0.054
Turkey	0.615	78.7%	12.6%	2.375	26.8%	0.069
Canada	0.816	62.8%	5.7%		54.6%	0.072
Malaysia	0.584	70.2%	13.1%	1.315	52%	0.031
Argentina	0.792	71.8%	21.6%		15.1%	0.036
Australia	0.781	59.8%	9.3%		16.1%	0.035
South Africa	0.579	68.1%	15.7%	1.557	34.2%	0.017
Colombia	0.63	82.1%	18.1%		10.5%	0.017
Peru	0.473	86.0%	18.9%	1.184	13.5%	0.012
Israel	0.75	79.9%	10.4%		31.4%	0.018

Note: TFP is manufacturing TFP relative to the US. Export growth is the share of export categories with a growth rate $< .5$ among exports with positive growth calculated among exports in the bottom quartile. Import decline is the share of import categories with a growth rate < 1 among imports with negative growth calculated among imports among the bottom 25-75 percentile. Import decline Poor/Rich is the share of import categories with declining imports from poor suppliers relative to share of import categories from rich suppliers with negative growth < -1 calculated among imports among the bottom 25-75 percentile. Export growth and import decline is average over successive five-year periods from 1991 through 2016 for each country in the 4-digit SITC trade data. Growth of total imports and exports normalized to zero for each country and five year period.

Table B2: General Empirical Moments

	Value
Share of categories with positive export, U.S.	45.4%
Exit Rate (Average of 20 countries)	19.2%
Growth	15.9%
Weighted Export Growth > 1	82.8%

Note: Row 1 is share of export categories in the U.S. with positive export growth (average over five-year periods from 1991 to 2016). Average exit rate is exit rate of exports in bottom quartile over 20 countries, where the exit rate of each country is the average exit rate over five year periods from 1991 to 2016. Growth is over a five year period.

Table B3: General Model Parameters

	Value
Imitation parameter α for 5 poorest countries	0.531
Imitation parameter α for 5 second-poorest TFP countries	0.449
Share of new products in new category κ_c	1.9%
Pareto Shape θ	18.173
Fixed Cost f	0.05
New Varieties Scale	0.886

Note: κ_c is the share of new products that are allocated to new export categories. θ is the shape parameter of the distribution of the innovation step size. f is the fixed cost in units of labor to sell in a market.

Table B4: Estimated Innovation Arrival Rates and Trade Cost

	Domestic Products λ	Imported Products δ	New Products κ	Trade Costs τ
US	93.8%	3.6%	77.6%	1.393
China	2.0%	8.0%	0.8%	2.640
EU	89.9%	5.7%	4.3%	1.087
Japan	84.9%	1.0%	51.6%	1.639
India	34.6%	5.6%	4.9%	2.593
Korea	44.5%	1.8%	22.7%	1.623
Indonesia	51.7%	1.6%	18.0%	2.197
Brazil	60.4%	1.1%	44.0%	1.971
Mexico	49.9%	7.9%	17.8%	1.246
Taiwan	46.1%	27.8%	28.0%	1.190
Thailand	66.2%	0.5%	32.7%	2.069
Turkey	59.7%	15.9%	17.6%	1.137
Canada	71.5%	8.3%	57.1%	1.019
Malaysia	63.9%	19.3%	48.9%	1.220
Argentina	74.2%	34.2%	44.7%	1.593
Australia	75.8%	35.1%	41.1%	1.019
South Africa	58.8%	23.0%	47.9%	1.238
Colombia	37.4%	19.0%	51.8%	1.202
Peru	45.0%	14.8%	22.5%	1.362
Israel	28.7%	78.0%	42.9%	1.033

Note: Table shows the arrival rate of innovation on domestic products (column 1), arrival rate on imported products (column 2), arrival rate of new products (column 3), and the gross trade cost (column 4).