A Global View of Creative Destruction

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Abstract

Exports exhibit the telltale sign of creative destruction on a global scale: simultaneous expansion and contraction across categories and firms. The exports of exporting firms are considerably more volatile than the domestic sales of the same firms. To mimic these patterns, we formulate a model of creative destruction by domestic and foreign firms. In the model, trade liberalization (or openness to idea flows more generally) quickens the pace of creative destruction and facilitates the flow of technology across countries. The resulting dynamic gains from idea flows are at least as large as the static gains from trade.

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1 Introduction

Studies by Bernard and Jensen (1999), Eaton and Kortum (2002), Melitz (2003), and others placed heterogeneous firms at the center of research on international trade. The first wave of follow-up research has mostly focused on models in which trade liberalization leads to a burst of reallocation and growth, but no long run effects on reallocation rates or growth rates.


In this paper we present facts and a model on the interaction of creative destruction and trade. We document ample reallocation of U.S. manufacturing exports at the 6-digit level across years. Expanding and contracting categories typically reallocate 18% of all exports (over and above growth in aggregate exports) over a five-year period. At the firm-level, meanwhile, we find that export growth — including entry and exit into exporting — is 50% more volatile than domestic sales growth of the same firms in the U.S. Census of Manufacturing. Thus exports are associated with elevated reallocation at the firm level, and ample churn at the 6-digit category level.

Motivated by these facts, we specify a model with global creative destruction. In our model, innovating firms improve upon existing technologies. When innovators take over the market for an existing product (creative destruction), export reallocation across countries can take place. Domestic firms can take over foreign markets for a product, and foreign firms can take over the domestic market. This is a two-economy version of the influential Klette and Kortum (2004) model of creative destruction, only with exogenous arrival rates in each country for simplicity.
In our baseline version of the model, innovators build on the technology of sellers. In this version trade facilitates the flow of ideas across countries. But we also consider a model in which ideas flow across countries independent of trade, as in Ramondo, Rodríguez-Clare and Saborío-Rodríguez (2016) and others. In both versions of the model, the diffusion of ideas generates a constant reallocation of exports between the two countries and results in the two economies growing at the same rate in the long run.

We calibrate the model to fit manufacturing moments in the U.S. vs. the rest of the OECD. We match TFP growth, relative value added per worker in the U.S. and the OECD, exports relative to all shipments (the trade share), and the sensitivity of trade to trade barriers (the trade elasticity). To pin down the Pareto shape parameter we fit the gap in revenue per worker for exporting vs. non-exporting firms in U.S. manufacturing. We also match employment in the U.S. vs the rest of the OECD. We infer higher innovation rates in the U.S. given its higher GDP per worker relative to the rest of the OECD.

Once calibrated, we analyze the model’s transition dynamics and steady state response to changes in tariffs. In the baseline version of the model, wherein ideas flow across countries due to trade, lower tariffs boost trade and the long run rate of export reallocation as well as growth. Even taking into account the transition, the gains from trade relative to autarky from the boost in idea flows are equivalent to a permanent 24% increase in consumption in the U.S. The rest of the OECD gains more than the U.S. from idea flows because the U.S. is more innovative.

In the alternative version of the model wherein idea flows are independent of trade, cutting tariffs has no effect on the growth rate. In this alternative model, increasing the flow of ideas across countries increases the long run growth rate and reduces trade. More idea flows lead to a narrower distribution of relative product quality across countries, thereby lowering the (standard) comparative advantage gains from trade. As in the baseline model, the rest of the OECD benefits more from idea flows than the U.S. because the U.S. is more innovative.
We also entertain versions of the model with severely limited idea flows. In one variant, countries learn almost entirely from dormant domestic producers when a product is imported, rather than from foreign sellers into the domestic market. In this event the gains from trade shrink toward the static gains. In another variant, countries specialize almost entirely in innovating on products they currently produce. Interestingly, the dynamic gains remain large for the U.S. Given its innovativeness, the U.S. gains a lot from concentrating its draws on a subset of products. The rest of the OECD enjoys smaller dynamic gains from research specialization. Models with limited idea flows and research specialization, however, predict much less reallocation of exports across categories than observed in the data.

Our effort is most closely related to three recent papers. Perla, Tonetti and Waugh (2020) study the impact of trade on exit, entry, domestic technology diffusion, and growth in a model of symmetric countries. Like us, they find large dynamic gains from trade. They derive analytical steady state solutions in a model of many countries, whereas we simulate a two-country model calibrated to evidence on export reallocation across products and firms. Our focus is on innovation, idea flows across countries, and creative destruction, whereas their focus is on the interaction of trade with domestic technology diffusion.

We follow Buera and Oberfield (2020) in studying international technology diffusion in a model with Bertrand competition. They endogenously obtain Frechet distributions of productivity within countries, allowing them to characterize multilateral trade flows as in Bernard, Eaton, Jensen and Kortum (2003). They stress that the dynamic effects of trade could be small or even negative depending on whether firms learn from domestic producers or from sellers into the domestic market. Our focus is more empirical, as we show our model matches evidence on export reallocation across categories and firms. We argue that these facts are consistent with knowledge flows across countries.

1In both variants we allow some idea flows to tether country technology levels and growth rates together, and keep comparative advantage from becoming too strong.
Like us, Akcigit, Ates and Impullitti (2018) characterize the impact of tariffs on growth in a two-country model with technology spillovers. Theirs is a step-by-step innovation model, with escape-from-competition effects through which trade can induce more innovation. They analyze transition dynamics and optimal R&D subsidies. They emphasize the convergence of patenting in other advanced countries toward patenting rates in the U.S. in recent decades. In our model and empirics, in contrast, we focus on how trade affects export reallocation at the category and firm levels.

The rest of the paper is organized as follows. Section 2 presents facts about export reallocation across categories and firms. Section 3 lays out the details of our baseline model. Section 4 describes alternative specifications with more limited knowledge spillovers. We devote Section 5 to calibrating the models and judging their fit. In Section 6 we assess the gains from trade (and idea flows more generally) in our model. Section 7 concludes.

2 Facts about export reallocation

We look at fluctuations in HS 6-digit manufacturing exports across five-year periods in the United Nation’s trade database. There are about 4,300 HS 6-digit manufacturing categories in the database, and we use the 2000-2005, 2005-2010, and 2010-2015 periods. We calculate the aggregate rate of export reallocation across categories in the same way that Davis, Haltiwanger and Schuh (1996) calculate job reallocation rates across firms.

We first divide exports of each manufacturing category at the end of each five year period \((t + 5)\) by the ratio of aggregate exports of the country at the end of the period \((t + 5)\) to aggregate exports at the beginning of the period \((t)\). This normalization nets out aggregate export growth, including from changes in price levels. We then add up the increase in exports in all categories showing an increase in exports from year \(t\) to year \(t + 5\), and then divide by aggregate exports in year \(t\). This is the export creation rate analogous to the job creation
rate introduced by [Davis, Haltiwanger and Schuh](1996). We can also calculate the export destruction rate by adding the decrease in exports in all categories showing a decline in exports between \( t \) and \( t + 5 \) and dividing by aggregate exports at \( t \). Given our normalization, the export destruction rate will be the same as the export creation rate.

Our focus is this export creation rate, or more precisely the “excess” export reallocation rate across categories above and beyond what would be needed to achieve the average growth rate of exports. We seek to gauge the magnitude of such reallocation because it could be a byproduct of creative destruction on a global scale. Due to creative destruction, a country may start exporting new things at the same time that it ceases exporting other things.

Table 1 shows excess export reallocation rates for the U.S., the OECD minus the U.S., and the rest of the world. Rates are averaged over 2000–2005, 2005–2010, and 2010–2015. For the rest of the OECD and world, we show the averages of the countries in each group weighted by total exports of the country. The export reallocation rate is about 20% over five years for the U.S. and the OECD countries, and around 28% for the non-OECD countries.

In Table 1 we also report the entry and exit rate of categories into and out of exporting over a five-year period. Specifically, the second row shows the average of (a) export sales at \( t \) of categories that are no longer exported by \( t + 5 \) (divided by aggregate exports at \( t \)), and (b) export sales at \( t + 5 \) of categories that were not exported at \( t \) divided by aggregate exports at \( t + 5 \). This extensive margin export reallocation rate is about 1% for the U.S. and the rest of the OECD, and roughly 2% for the non-OECD countries.

Figure 1 shows that the export reallocation rate is just as large for product categories with large exports as categories with small export values. For each country and five year period, we grouped categories with positive exports at \( t \) into ten bins (with the same number of categories in each bin) based on the

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\( ^2 \)Our statistics on export reallocation are related to the measure of mean reversion of a country’s top exporter documented in [Hanson, Lind and Muendler](2018).
Table 1: Export reallocation facts

<table>
<thead>
<tr>
<th></th>
<th>U.S.</th>
<th>Rest of OECD</th>
<th>Non-OECD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Excess export category reallocation</td>
<td>18.2%</td>
<td>20.1%</td>
<td>28.7%</td>
</tr>
<tr>
<td>Category entry and exit rates</td>
<td>1.2%</td>
<td>1.0%</td>
<td>2.3%</td>
</tr>
</tbody>
</table>

Note: Authors’ calculations using the UN’s HS-6 digit level trade database. Export reallocation is calculated across HS-6 digit categories, and is averaged across the three five-year periods 2000-2005, 2005-2010, and 2010-2015. The export reallocation rate is the sum of increases in exports (relative to the aggregate rate) in categories where exports grew (including new export categories) divided by aggregate exports of the country in the first year of each five-year period. Extensive margin reallocation is the average of the category entry and exit rates. The entry rate is the share of aggregate exports in new categories in the ending year, and the exit rate is the share of aggregate exports in exiting categories in the initial year. Rest of OECD and Rest of World are averages of countries weighted by the country’s total exports.

Figure 1: Export destruction rates by size of exported category

Note: Figure shows export destruction rate over five years for categories within each size decile calculated from the UN’s HS-6 digit trade database. We show the average from 2000-2005, 2005-2010, and 2010-2015. Size calculated as value of exports of each category at beginning of each period. Export destruction rate is sum of change in exports across all categories within each bin with declining exports between $t$ and $t+5$ divided by the total value of exports of all categories in each bin at $t$. Rest of OECD and Rest of World are averages of countries weighted by the country’s total exports.
value of exports in each category. Within each of the ten bins we added the change in exports for the categories where exports fall between $t$ and $t + 5$ and divide by the total exports of the categories in each bin at $t$. The export reallocation rate in the bin with the top 10% of U.S. exports is about 20% over five years, which is similar to the overall U.S. export reallocation. For the rest of the OECD and the rest of the world, the export reallocation for the largest export categories is higher than that for the smallest export categories. In the OECD, the export reallocation rate is about 20% for the top 10% of export categories and 10% for the bottom 10% of categories. For the rest of the world, the export destruction rate of the largest export categories is more than three times larger than that of the smallest export categories. This Figure drives home that even a country’s largest export categories experience ample churn.

Our last set of facts are about the volatility of exports vs. domestic sales at the firm level. We use the U.S. Census of Manufactures to calculate firm-level exports and domestic sales. We analyze this data every five years between 1987 and 2012. Exports became available in the Census micro-data in 1987, and 2012 is the latest year for which we have access. We obtain domestic sales by subtracting exports from total sales at the firm level. We calculate five-year growth rates at the firm level, then compute the standard deviation of these growth rates across firms. To take into account firms entering and exiting (either exports or domestic sales), we take the arc growth rate — i.e., the change in exports (or domestic sales) divided by the average of current and previous period exports (or domestic sales).

The results are shown in Table 2 below. Across firms, export growth is more dispersed than is domestic sales growth, especially if one compares them within exporting firms. The standard deviation is 1.72 for export growth and 1.20 for domestic sales of exporting firms. This pattern is consistent with the notion that exporting exposes a firm to creative destruction from a foreign firm to a greater extent than does selling in the domestic market. Both types of sales are subject to creative destruction from other domestic firms.
Table 2: U.S. firm sales volatility facts

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Standard Deviation (S.D.) of export growth</td>
<td>1.72</td>
</tr>
<tr>
<td>S.D. of domestic sales growth for exporting firms</td>
<td>1.20</td>
</tr>
<tr>
<td>S.D. of domestic sales growth for all firms</td>
<td>1.50</td>
</tr>
</tbody>
</table>


3 Baseline model

This section presents a model of growth driven by creative destruction, where innovation can come from domestic or foreign firms.

3.1 Static equilibrium

The static part of our model is similar to Bernard et al. (2003), or to Dornbusch, Fischer and Samuelson (1977) only with markup heterogeneity.

Utility of the home-country representative consumer is given by consumption of a continuum of varieties $C_j$ with measure 1:

$$U = \int_0^1 \ln C_j \, dj.$$ 

This utility function implies that consumers spend the same on each variety.3

Output of each variety is the product of labor and the quality of the blueprint for the product. We denote $A_j$ as the “best” blueprint for $j$ among domestic firms. $A_j^*$ is the corresponding best blueprint for $j$ among foreign firms. If we order products so that the index $j$ is decreasing in $A_j/A_j^*$, then products $j \in [0, x]$ are traded and produced at home, $j \in [x, x^*]$ are non-traded, and $j \in [x^*, 1]$ are

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3 Utility of the foreign consumer is analogously given by $U^* = \int_0^1 \ln C_j^* \, dj$. 
## Table 3: Markups

<table>
<thead>
<tr>
<th></th>
<th>Traded Produced in home</th>
<th>Non-traded</th>
<th>Traded Produced in foreign</th>
</tr>
</thead>
<tbody>
<tr>
<td>Home</td>
<td>$A_j$</td>
<td>$A_i$</td>
<td>$A^*_j/\tau$</td>
</tr>
<tr>
<td></td>
<td>$\max \left[ A'_{j, \omega A^*_j/\tau} \right]$</td>
<td>$\max \left[ A'_{j, \omega A^*_j/\tau} \right]$</td>
<td>$\max \left[ A^*_j, \frac{A_j}{\tau} \right]$</td>
</tr>
<tr>
<td>Foreign</td>
<td>$A_j/\tau$</td>
<td>$A^*_j$</td>
<td>$A^*_j$</td>
</tr>
<tr>
<td></td>
<td>$\max \left[ A'_{j, \omega A^*_j/\tau} \right]$</td>
<td>$\max \left[ A^*_j, \frac{A_j}{\tau} \right]$</td>
<td>$\max \left[ A^*_j, \frac{A_j}{\omega \tau} \right]$</td>
</tr>
</tbody>
</table>

traded and produced abroad. The cutoff products $x$ and $x^*$ are defined by:

$$\frac{A_x}{\tau} = \omega A^*_x$$

$$A_{x^*} = \frac{\omega A^*_x}{\tau}$$

where $\omega$ denotes the relative wage (domestic relative to foreign) and $\tau \geq 1$ is the symmetric gross tariff rate. When $\tau = 1$, $x = x^*$ and all products are traded.

The owner of the best blueprint sets their quality-adjusted price to push their closest competitor out of the market (Bertrand competition), so the gross markup is the gap between the incumbent firm’s marginal cost and the cost of its closest competitor — domestic or foreign. Table 3 summarizes the markups: $\mu_j$ for domestic firms and $\mu^*_j$ for foreign firms. $A'_{j}$ and $A^*_j$ denote the productivity of the second best producer in the domestic and foreign countries. These potential competitors do not produce in equilibrium but affect markups.

The relative wage is pinned down by balanced trade:

$$I^* \cdot x = I \cdot (1 - x^*)$$  \hspace{1cm} (1)

where $I$ and $I^*$ denote nominal GDP at home and abroad, respectively. The left hand side of equation (1) is the home country’s exports and the right hand side
is the home country’s imports. Nominal GDP in each country is given by

\[ I = \frac{\bar{\mu} w L}{1 - \frac{1-x}{\tau} \cdot (1 - x^*)} \]

\[ I^* = \frac{\bar{\mu}^* w^* L^*}{1 - \frac{1-x}{\tau} \cdot x} \]

where \( \bar{\mu}^* \) and \( \bar{\mu} \) denote the average gross markup of foreign and domestic firms, \( w \) and \( w^* \) are the home and foreign wage, and \( L \) and \( L^* \) are labor supply at home and abroad.\(^\text{4}\)

More exactly, the average price-cost markup in the U.S. satisfies

\[ \frac{1}{\bar{\mu}} \equiv \frac{\int_{0}^{x^*} \frac{1}{\mu_j} dj + \frac{1}{\tau} \cdot \int_{0}^{x} \frac{1}{\mu^*_j} dj}{x^* + x/\tau} \]

where \( \mu^*_j \) denotes the markup of domestic firms on their exported products. The expression for the foreign firms’ average markup is analogous.

We can express the real (consumption) wage as a function of the distribution of the best blueprints, markups, the cutoffs, the relative wage, and the tariff rate. The real wages at home \( W \) and in the foreign country \( W^* \) are given by

\[ \ln W = \int_{0}^{x^*} \ln \left( \frac{A_j}{\mu_j} \right) dj + \int_{x^*}^{1} \ln \left( \frac{A^*_j}{\mu^*_j} \cdot \frac{\omega}{\tau} \right) dj \]

\[ \ln W^* = \int_{0}^{x} \ln \left( \frac{A_j}{\mu_j} \cdot \frac{1}{\omega \tau} \right) dj + \int_{x}^{1} \ln \left( \frac{A^*_j}{\mu^*_j} \right) dj. \]

The home country buys \( j \in [x^*, 1] \) from the foreign country, so the domestic real wage is increasing in the productivity of foreign firms on these products. Likewise, the foreign country purchases \( j \in [0, x] \) from the home country, so the foreign real wage increases with domestic firm productivity on these products.

\(^\text{4}\)The expression for nominal income comes from equating nominal income to the revenue of local firms plus tariff revenue: \( I = \bar{\mu} w L + (\tau - 1) \frac{1}{\tau} (1 - x^*) \) and \( I^* = \bar{\mu}^* w^* L^* + (\tau - 1) \frac{1}{\tau} \cdot x. \)
3.2 Innovation

We now introduce dynamics to the model. As in Klette and Kortum (2004), a firm is a portfolio of products, an entrant has one product while incumbent firms potentially produce many varieties, and innovation only takes the form of creative destruction. We posit constant exogenous arrival rates for innovation. Arrivals are proportional to the number of products owned by a firm; a firm with two products is twice as likely to creatively destroy another firm’s variety compared to a firm with one product. We assume that innovation builds on the quality of the product that is being creatively destroyed.

We depart from Klette and Kortum (2004) by allowing a product made in one country to be creatively destroyed by a firm in another country. Table 4 summarizes the arrival rates of innovation. The probability a product is improved upon by an incumbent domestic firm is \( \lambda \), whereas \( \eta \) is the probability the product is improved by an entering domestic firm. Analogously, \( \lambda^* \) is the probability the product will be improved by a foreign incumbent firm, and \( \eta^* \) is the probability a foreign entrant innovates on the best blueprint. In short, a given product can be improved upon by a domestic incumbent firm, a domestic entrant, a foreign incumbent firm, or a foreign entrant.

The product quality yielded by an innovation follows a Pareto distribution with shape parameter \( \theta \) and scale parameter equal to the existing quality level. The average percent improvement in quality over an existing variety (conditional on innovation) is thus \( 1/(\theta - 1) > 0 \). We add a “reflecting barrier” whereby each year the bottom \( \psi \) percent of products, in terms of their quality, redraw their quality from the top \( 1-\psi \) percent of domestically produced products. This

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5 In an earlier version of the paper we endogenized arrival rates as a function of research labor. The model’s steady state properties are very similar, even in response to trade liberalization. See Hsieh, Klenow and Nath (2019).


7 These are all unconditional probabilities of innovation. The underlying conditional probabilities avoid duplication of arrivals on the same product in a given year.
Table 4: Channels of innovation

<table>
<thead>
<tr>
<th></th>
<th>Domestic firms</th>
<th>Foreign firms</th>
</tr>
</thead>
<tbody>
<tr>
<td>Innovation by incumbents</td>
<td>λ</td>
<td>λ*</td>
</tr>
<tr>
<td>Innovation by entrants</td>
<td>η</td>
<td>η*</td>
</tr>
</tbody>
</table>

Note: The average improvement in quality for each innovation is \( \frac{1}{\theta - 1} \).

is in the spirit of what Perla et al. (2020) obtain endogenously, and will help maintain a stationary distribution of quality across products (relative to the growing mean quality) in response to innovation.

3.3 Trade-embodied knowledge flows

Our baseline assumption is that innovators build on the quality of the products sold in the innovating firm’s local market. That is, spillovers of knowledge across countries are embodied in trade. In the absence of trade, innovation draws occur only based on the quality of the current domestic producer.

Table 5 summarizes the odds of creative destruction when innovators build on the quality of products sold in the local market. The probability of creative destruction depends on whether a product is traded or only sold in the local market. The first column shows the rate of creative destruction by domestic firms and the second column by foreign firms. The first row shows the arrival rate of ideas in the domestic market for an exported product. The probability such a product is improved upon by another domestic firm is \( \lambda + \eta \). A domestic innovator will always replace the incumbent firm in this market. A foreign firm improves upon the same product with probability \( \lambda^* + \eta^* \). But foreign innovators will not necessarily replace the domestic incumbent. Since quality follows a Pareto distribution, the probability that the quality of the foreign innovator is large enough to replace the domestic incumbent is \( \min \left( \left( \frac{\omega}{\tau} \right)^\theta, 1 \right) \).
Table 5: Probability of creative destruction

<table>
<thead>
<tr>
<th>Market</th>
<th>Product type</th>
<th>Domestic firm</th>
<th>Foreign firm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Home</td>
<td>Exported by home</td>
<td>$\lambda + \eta$</td>
<td>$(\lambda^* + \eta^*) \min \left(\frac{(\omega)}{\tau}, 1\right)$</td>
</tr>
<tr>
<td></td>
<td>Non-traded</td>
<td>$\lambda + \eta$</td>
<td>$(\lambda^* + \eta^<em>) \min \left(\frac{(\omega A^</em>_j)}{(\tau A^*_j)}, 1\right)$</td>
</tr>
<tr>
<td></td>
<td>Imported by home</td>
<td>$(\lambda + \eta) \min \left(\frac{(x_j)}{(\omega)}, 1\right)$</td>
<td>$\lambda^* + \eta^*$</td>
</tr>
<tr>
<td>Foreign</td>
<td>Exported by home</td>
<td>$\lambda + \eta$</td>
<td>$(\lambda^* + \eta^*) \cdot \min \left(\frac{(\omega)}{\tau}, 1\right)$</td>
</tr>
<tr>
<td></td>
<td>Non-traded</td>
<td>$(\lambda + \eta) \min \left(\frac{(A^<em>_j)}{(\omega A^</em>_j)}, 1\right)$</td>
<td>$\lambda^* + \eta^*$</td>
</tr>
<tr>
<td></td>
<td>Imported by home</td>
<td>$(\lambda + \eta) \min \left(\frac{(1)}{(\omega A^*_j)}, 1\right)$</td>
<td>$\lambda^* + \eta^*$</td>
</tr>
</tbody>
</table>

Higher relative wages $\omega$ and lower tariffs $\tau$ increase the probability that innovation by a foreign firm benefits domestic consumers. Higher domestic wages increase the probability a foreign innovator will be competitive enough to replace the incumbent in the domestic market. Higher tariffs make the foreign innovator less competitive compared to the domestic incumbent. Tariffs insulate domestic firms from foreign competition in the domestic market.

The expected growth in the domestic real consumption wage is the product of the rate of creative destruction in rows 1-3 in Table 5 and the increases in product quality (conditional on the product being replaced): \[ g = (\lambda + \eta) \left[ \frac{x^*}{\theta - 1} + (1 - x^*) \min \left\{ 1, \left(\frac{\tau}{\omega}\right)^\theta \right\} \left(\frac{\theta}{\theta - 1} \cdot \max \left\{ \frac{\omega}{\tau}, 1 \right\} - 1 \right) \right] + (\lambda^* + \eta^*) \left[ \frac{1 - x^*}{\theta - 1} + (x^* - x) \min \left\{ 1, \left(\frac{\omega}{\tau} \cdot \frac{A^*_j}{A^*_j}\right)^\theta \right\} \left(\frac{\theta}{\theta - 1} \cdot \max \left\{ \frac{\tau}{\omega}, 1 \right\} - 1 \right) \right] + (\lambda^* + \eta^*) \left[ x \cdot \min \left\{ 1, \left(\frac{\omega}{\tau}\right)^\theta \right\} \left(\frac{\theta}{\theta - 1} \cdot \max \left\{ \frac{\tau}{\omega}, 1 \right\} - 1 \right) \right] \]

\[^8\text{Here we abstract from the reflecting barrier at the low end of the quality distribution.}\]
where $\left[ \frac{A_j}{A_j^*} \right] \equiv \int_x^{x^*} (A_j^*)^2 dj$ and $\left[ \frac{A_j}{A_j^*} \right] \equiv \int_x^{x^*} (A_j/A_j^*)^2 dj$. The first line is the contribution of innovation by domestic firms; the second and third lines are the contribution of foreign firms. The expected growth rate of the foreign real consumption wage is analogously the product of the arrival rates in rows 4-6 in Table 5 and the corresponding improvements in quality.

Note the growth rates in the two countries depend on the arrival rates of innovation ($\lambda + \eta$ and $\lambda^* + \eta^*$), the relative wage ($\omega$), and the share of each products exported by each country ($x$ and $1 - x^*$). As discussed previously, the relative wage and the share of products made by each country are pinned down by balanced trade and the distribution of relative technologies $A_j/A_j^*$. The distribution of $A_j/A_j^*$ is endogenous to innovation.

To illustrate how quality advances as each country builds on the innovations of the other country, it is useful to consider the case of completely free trade ($\tau = 1$). In this case, all products are traded so the probability a domestic firm creatively destroys another firm is thus given by:

$$\text{Domestic creative destruction rate} = (\lambda + \eta) \cdot x^* + (\lambda + \eta) \min [\omega^{-\theta}, 1] \cdot (1 - x^*).$$

The first term is the probability a domestic firm replaces a product made by another domestic firm and the second term is the probability a domestic firm replaces a variety produced by a foreign firm. The corresponding rate of creative destruction by a foreign firm under free trade ($\tau = 1$) is:

$$\text{Foreign creative destruction rate} = (\lambda^* + \eta^*) \cdot (1 - x^*) + (\lambda^* + \eta^*) \min [\omega^\theta, 1] \cdot x^*.$$  

Ceteris paribus, higher $\omega$ lowers the rate of creative destruction of domestic firms and raises that of foreign firms. In steady state, the equilibrium relative wage equates the rate of creative destruction by domestic firms to that of foreign firms. So, if domestic firms are more innovative, domestic wages are higher but the creative destruction rate of domestic firms is the same as for foreign firms.
It is also helpful to contrast autarky and free trade when the two countries are symmetric in size and in their innovation arrival rates. In this special case the relative wage $\omega = 1$ and the growth expressions become simply:

$$\text{Autarky growth rate} = (\lambda + \eta) \frac{1}{\theta - 1}$$

$$\text{Frictionless growth rate} = 2 \cdot (\lambda + \eta) \frac{1}{\theta - 1}.$$ 

In autarky each country benefits only from domestic arrivals. With frictionless trade, each country benefits from both domestic and foreign arrivals. The doubling of growth under free trade compared to autarky underscores the scale effect generating dynamic gains from trade in this model.

Figure 2 illustrates the effect of changing tariffs in the model. It shows the growth rate, trade share, and the local trade elasticity across steady-states with different tariff rates. The left panel shows that higher tariffs lower the common long run growth rate of the two economies. When fewer goods are traded, countries are less frequently building on each other’s innovations and more frequently building only on their own innovations. The middle panel in Figure 2 shows that higher tariffs lower the trade share, as one would expect. Less obviously, the right panel in the Figure reveals that the trade elasticity also falls with the tariff rate.

Figure 3 shows why the trade elasticity varies with the tariff rate when idea flows are facilitated by trade. The left panel plots the dispersion across products of quality in the home relative to the foreign country in a steady state with high tariffs ($\tau = 4$) vs. with low tariffs ($\tau = 1.5$). Lower tariffs narrow the dispersion of relative quality, as ideas flow more quickly across countries with more trade. When technologies are more similar across countries, the response of trade flows to changes in tariffs is correspondingly higher.

---

9The numbers in the figure are for illustrative purposes only. We discuss the precise calibration of the model in detail in a later section.
**Figure 2:** Effect of tariffs with knowledge spillovers embodied in trade

<table>
<thead>
<tr>
<th>Growth rate</th>
<th>Trade share</th>
<th>Trade elasticity</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image1.png" alt="Graph" /></td>
<td><img src="image2.png" alt="Graph" /></td>
<td><img src="image3.png" alt="Graph" /></td>
</tr>
</tbody>
</table>

Gross tariff rate $\tau$

**Figure 3:** Effect of tariffs on relative quality dispersion

<table>
<thead>
<tr>
<th>Trade-embodied spillovers</th>
<th>Disembodied spillovers</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image4.png" alt="Graph" /></td>
<td><img src="image5.png" alt="Graph" /></td>
</tr>
</tbody>
</table>

Gross tariff rate $\tau$
3.4 Disembodied idea flows

In our baseline model, foreign innovators learn about domestic technologies from trade. We now consider a model wherein the flow of ideas across borders is not related to trade. First sort the products indexed by $i \in [0, 1]$ by the ratio of the domestic productivity to foreign productivity $A_j / A_j^*$. Now suppose foreign innovators draw with probability $z$ on a random domestic product from $i \in [0, z]$ and with probability $1 - z$ on a random foreign product from $i \in [z, 1]$. And domestic innovators innovate with probability $z^*$ on a random foreign product from $i \in [z^*, 1]$ and with probability $1 - z^*$ on a random domestic product from $i \in [0, z^*]$. Spillovers from the domestic to foreign innovators is thus increasing in $z$, and spillovers from foreign blueprints to domestic innovators is increasing in $z^*$. We call this the “disembodied spillover” model since the knowledge spillovers are not related to trade.

In the disembodied spillover model, creative destruction from foreign innovators takes place when the foreign innovators targets a domestic variety. Likewise a foreign variety is creatively destroyed when a domestic innovator targets a foreign variety. Moreover, it is easy to see that the disembodied spillovers model is equivalent to our baseline model where idea flows are embodied in trade if the steady state features $z = x$ and $z^* = x^*$, where $x$ and $x^*$ are the fraction of products exported by the domestic and the foreign country, respectively.

The two models differ in that trade is essential to spillovers in the baseline model and unrelated to idea flows in the disembodied spillover model. In the latter, the key parameters that govern spillovers are the spillover thresholds $z$ and $z^*$. Figure 4 illustrates the effect of the spillover threshold by showing the growth rate, trade share, and trade elasticity in steady states with different values of the spillover threshold for foreign innovators $z$. Remember the spillover of domestic ideas to foreign innovators increases as $z$ rises. The growth rate rises as ideas flow more quickly from the domestic to foreign innovators with a higher $z$. On the other hand, the trade share falls and the trade elasticity rises as
foreign qualities hug the domestic ones more closely in response to higher $z$.

**Figure 4:** Effect of spillover threshold with disembodied knowledge flows

![Graph showing the effect of spillover threshold on growth rate, trade share, and trade elasticity](image)

Notice that the growth rate is negatively correlated with the trade share in the disembodied spillover model, whereas the correlation was positive in the model where spillovers are embodied in trade flows. In the two models, the growth rate rises and technology differences between the two countries narrow as ideas flow more frequently across countries. The narrowing of technology differences in the model comes from more trade in the trade-embodied spillover model, while trade has no effect on spillovers in the disembodied model. The right panel in Figure 3 above illustrates this by showing the dispersion of relative quality in the disembodied spillover model in steady states with high vs. low tariffs. The Figure shows that tariffs have no effect on the dispersion of relative qualities in this model, as the frequency of idea flows across countries is unrelated to trade in this model.
4 Export reallocation with limited idea flows

The central feature of the models laid out in the previous section is that ideas flow across countries. In this section, we show that models where idea flows are limited cannot “explain” the export reallocation observed in the data.

We first limit idea flows by lowering the probability that innovators build on the designs of imported products. Specifically, suppose that innovators build on foreign producers of imported products with probability $\kappa$, and on the last domestic producer with probability $1 - \kappa$. We consider a low value of $\kappa = 0.1$ to contrast with our baseline model where $\kappa = 1$. If 10% of the consumed products in a country are imports, our baseline model with $\kappa = 1$ implies that 10% of the innovations build upon foreign designs. In the model with $\kappa = 0.1$, however, only 1% of domestic innovators improve upon foreign varieties. We cannot handle building only on domestic producers ($\kappa = 0$), because in that case country growth rates diverge in response to their differing arrival rates.

Our second way to limit idea flows is to assume that innovators build on all products with probability $\nu$, and on the subset of products that are domestically produced with probability $1 - \nu$. Such research specialization ($\nu < 1$) allows countries to experience more frequent innovations on the subset of products they produce, and more so the higher the share of products imported. Whereas our baseline model has $\nu = 1$ and $\kappa = 1$, we will consider $\nu = 0.1$ and $\kappa = 0.1$ as a contrasting case with research specialization. With these parameter values, the probability a domestic innovator builds upon the design of a foreign producer is even lower at 0.1% (assuming imports account for 10% of consumed varieties). Again, we cannot handle the polar extreme of $\nu = 0$ because in that case the two countries will have different long run growth rates.

In Table 6 we compare the properties of our baseline model to the models with limited idea flows. In this exercise we hold fixed all parameters except $\kappa$ and $\nu$. Table 6 shows that the baseline model yields more reallocation of exports across categories than when innovators build mostly on domestic quality and,
Table 6: Export reallocation in models with limited idea flows

<table>
<thead>
<tr>
<th></th>
<th>Baseline</th>
<th>Limited idea flows</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$\kappa = 1$</td>
<td>$\kappa = 0.1$</td>
</tr>
<tr>
<td></td>
<td>$\nu = 1$</td>
<td>$\nu = 0.1$</td>
</tr>
</tbody>
</table>

Export category reallocation rate

<table>
<thead>
<tr>
<th></th>
<th>Baseline</th>
<th>Limited idea flows</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>14.3%</td>
<td>6.0%</td>
</tr>
<tr>
<td>(S.D. of export growth)/(S.D. of domestic sales growth)</td>
<td>1.65</td>
<td>1.25</td>
</tr>
</tbody>
</table>

Note: All parameters are held fixed across the models except the spillover parameters $\kappa$ (the share of innovation building on seller productivity) and $\nu$ (the share of innovation building on the productivity of products a country produces).

especially, when innovation also focuses on products that a country currently produces. Specializing innovations to what a country is already good at reinforces comparative advantage and leads to minimal export category turnover. Table 6 also shows that, in the baseline model, firm-level export sales growth is much more dispersed than domestic sales growth. The standard deviation of export sales is 65% larger than the standard deviation of domestic sales of the same firms. This is notably less true when innovators build on domestic quality levels. And it is not at all true when countries also specialize their arrivals on the products they already produce.

5 Calibration and fit

Our baseline model involves 8 parameters: the shape $\theta$ of the Pareto distribution of innovation draws; two innovation rates (for incumbents $\lambda$ and entrants $\eta$) in each country; the tariff rate $\tau$; the rate at which the number of products in a category rises when we rank categories from low to high total exports $\epsilon$; and the fraction of low quality products that redraw from the remainder of the domestic quality distribution each year $\psi$. 
Table 7: Data moments used for calibration

<table>
<thead>
<tr>
<th>Data Moment</th>
<th>Source</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Revenue per worker exporters/non-exporters</td>
<td>U.S. Census of Manufacturing</td>
<td>1.066</td>
</tr>
<tr>
<td>TFP growth rate</td>
<td>BLS data for U.S. manufacturing</td>
<td>3.01%</td>
</tr>
<tr>
<td>Value added per worker home/foreign</td>
<td>KLEMS for U.S. and OECD mfg.</td>
<td>1.29</td>
</tr>
<tr>
<td>Employment share of entrants</td>
<td>U.S. census of Manufacturing</td>
<td>14.4%</td>
</tr>
<tr>
<td>Export share of revenues (home)</td>
<td>U.S. Census of Manufacturing</td>
<td>10.2%</td>
</tr>
<tr>
<td>Trade elasticity</td>
<td>Head and Mayer (2014)</td>
<td>5</td>
</tr>
<tr>
<td>Employment home/foreign</td>
<td>KLEMS for U.S. and OECD mfg.</td>
<td>0.389</td>
</tr>
<tr>
<td>Exports in 75th/25th HS-6 Category</td>
<td>UN Trade Database</td>
<td>20</td>
</tr>
<tr>
<td>Number of HS-6 Categories</td>
<td>UN Trade Database</td>
<td>4,250</td>
</tr>
</tbody>
</table>

We infer the value of these eight parameters from the first 7 data moments listed in Table 7. We do not separately identify the arrival rate of innovations by foreign entrants vs. incumbents, but rather assume this breaks down in the same way the U.S. ratio breaks down.

As mentioned, the U.S. is “home” and the rest of the OECD is “foreign.” We back out $\theta$ from the gap in labor productivity (revenue per worker) between exporters and non-exporters. The higher is $\theta$, the smaller the variance in the innovation step size and the smaller the gap between exporter and non-exporter markups. In the U.S. data revenue per worker of exporters is 6.6% higher than that of non-exporters.

For a given $\theta$ and relative employment $L/L^*$, the innovation arrival rates and the tariff rate ($\tau$) jointly determine the growth rate, the trade share, and the relative wage. We target a growth rate of 3%, relative employment (U.S./OECD) of 0.389, a U.S. trade share of 10%, and a relative wage (U.S./OECD) of 1.29\(^\text{10}\)

---

\(^{10}\) We set home/foreign employment to directly match the data for the U.S. relative to the rest of the OECD in the World KLEMS Database.
We use the employment share of new firms in U.S. manufacturing to pin down innovation by entrants vs. incumbents. The U.S. employment share of firms with age < 5 is 14.4%. Finally, we assume a trade elasticity of 5 to back out the reflecting barrier $\psi$ and the implied dispersion of product qualities.

To compare the model to the data in terms of export reallocation across categories, we need to take a stand on the number of products in each category in the export data. We assume the smallest category has one product and that the number of products in a category increases at the exponential rate $\epsilon$ as one goes from smallest to largest categories. We then choose the total number of products in the model and $\epsilon$ to match two numbers in the UN trade data: the number of categories and the ratio of 75th to 25th percentile category exports. There are 4,250 HS-6 categories and the 75/25 ratio is a factor of 20 for U.S. exports. We fit these two data moments with 217,000 products and $\epsilon = 0.133$.

We simulate the arrival of innovations on each variety, with draws randomly assigned to an existing incumbent or a new entrant. The relative wage is found that balances trade between the two countries in each year. We simulate for several hundred years until the economy settles down to a steady-state, at which point we calculate moments. We utilize a simulated annealing procedure to search for the parameter values that match the data moments.

The resulting calibrated parameter values are shown in Table 8. The U.S. combined innovation rate for incumbents and entrants is about $\lambda + \eta = 16\%$, and the OECD combined innovation rate is roughly $\lambda^* + \eta^* = 12\%$. The innovation rate has to be higher for domestic firms to explain the 29% higher real wage (real value added per worker) in the U.S. than in the OECD. Conditional on the innovation rates and the relative size of the two economies, the trade share pins down the tariff rate at 50\%. Finally a reflecting barrier where the bottom 1.0% of products by quality redraw from the top 99.0% of domestic products generates a trade elasticity of 5. A higher $\psi$ narrows the quality distribution and weakens comparative advantage, thereby raising the trade elasticity.

\[^{11}\text{Eaton and Kortum (2002) and others infer high trade costs to explain bilateral trade flows.}\]
Table 8: Model parameter estimates

<table>
<thead>
<tr>
<th>Variable</th>
<th>Description</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\theta$</td>
<td>Shape parameter of innovation draws</td>
<td>10.8</td>
</tr>
<tr>
<td>$\lambda$</td>
<td>Home innovation rate from incumbents</td>
<td>13.5%</td>
</tr>
<tr>
<td>$\eta$</td>
<td>Home innovation rate from entrants</td>
<td>2.5%</td>
</tr>
<tr>
<td>$\lambda^* + \eta^*$</td>
<td>Foreign innovation rate from incumbents + entrants</td>
<td>12.2%</td>
</tr>
<tr>
<td>$\tau$</td>
<td>Gross tariff rate</td>
<td>1.50</td>
</tr>
<tr>
<td>$\psi$</td>
<td>Reflecting barrier for product quality</td>
<td>1.0%</td>
</tr>
</tbody>
</table>

Table 9 shows the three trade moments — the export category reallocation rate, the relative volatility of exports vs. domestic sales, and the trade elasticity — in the baseline model with the parameter values shown in Table 8. The first column gives the three moments in the data, and the second column shows the simulated value of these moments in the baseline model. The export reallocation rate in the baseline model with idea flows is 14.3% compared to 18.2% in the data. The ratio of the volatility of export sales to domestic sales in the baseline model is 1.65, which is slightly higher than the 1.43 in the data. We did not target these two moments to obtain the model parameters. We did target the trade elasticity of 5 in the baseline model.

The last two columns in Table 9 show the trade moments in the models with limited idea flows. These moments differs from the trade moments shown earlier in Table 6 because there we kept all parameters constant except for the parameters that govern idea flows. In Table 9 we re-estimate all the parameters to fit the same data moments in Table 7. All of the models fit the 3% aggregate TFP growth target, the U.S./OECD wage gap of 29%, the 10.2% U.S. export share, and the 14.4% employment share of entering firms. As the first row of Table 9 makes clear, however, the models with limited ideas flows generate far too little export turnover relative to the data. This is the key discrepancy that motivates
Table 9: Trade moments, data vs. model

<table>
<thead>
<tr>
<th></th>
<th>Baseline</th>
<th>Limited idea flows</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$\kappa = 1$</td>
<td>$\kappa = 0.1$</td>
</tr>
<tr>
<td></td>
<td>$\nu = 1$</td>
<td>$\nu = 1$</td>
</tr>
<tr>
<td>Export category reallocation rate</td>
<td>18.2%</td>
<td>14.3%</td>
</tr>
<tr>
<td>S.D. of growth exports/(domestic sales)</td>
<td>1.43</td>
<td>1.65</td>
</tr>
<tr>
<td>Trade elasticity</td>
<td>5</td>
<td>5</td>
</tr>
</tbody>
</table>

Notes: The model parameters are re-estimated in each model to fit the data moments in Table 7. The spillover parameters are $\kappa$ (the share of innovation building on sellers) and $\nu$ (the share of innovation building on products a country produces).

us to emphasize models with idea flows and global creative destruction. The models with limited idea flows do generate more volatility for export growth than for domestic sales growth within firms, perhaps because of the effects of tariffs and wage differentials (and some idea flows). But the models with limited flows cannot fit a trade elasticity of 5. The reason is that, with limited spillovers, country quality levels spread out so much across products that comparative advantage becomes strong and the trade elasticity becomes small.

In the model wherein idea flows are independent of trade, there are two additional parameters, the idea spillover thresholds $z$ and $z^*$. As noted earlier, when $z$ is equal to the U.S. export share and $z^*$ is equal to the foreign export share, then the disembodied idea flows model generates the same moments as the model wherein idea are embodied in trade. In our baseline model with trade-embodied spillovers, the U.S. exports 14.7% and the rest of the OECD exports 7.8% of all products. To get an independent estimate of $z$ and $z^*$, we would need more data moments in addition to those in Table 7.
6 Gains from trade and idea flows

In this section, we calculate the welfare gain from trade and idea flows. In the model wherein idea flows are embodied in trade, the gross tariff rate $\tau$ is the key parameter that determines the extent to which ideas flow between countries. In this case, a decrease in $\tau$ results in both static gains from trade and dynamic gains from more idea flows.

Table 10 shows the welfare gains from reducing tariffs in the model with trade-embodied idea flows. We calculate the gains as the equivalent variation (permanent percentage change) in consumption, with log utility and a discount rate of 1.9% to match a real interest rate of 5% given the TFP growth rate of 3%. In this model, there are two sources of gains from trade: the standard static gains from exploiting comparative advantage, and the dynamic gains from more idea flows. The first two columns show these effects when tariffs are lowered from $\tau = 1.5$ to $\tau = 1.25$. The last two columns show the gains from moving from near autarky, where the trade share is around 0.4%, to the baseline where the trade share is 10.2%.

The first row in Table 10 shows the static welfare gains from reducing tariffs. We calculate the static gains as the permanent consumption-equivalent from reducing $\tau$ while keeping fixed both idea flows and the distribution of productivity in the two countries fixed. The static gains from cutting tariffs in half are 5.5% for the U.S. and 3.5% for the rest of the OECD. The corresponding static gains from moving from autarky to our baseline tariff (implying a trade share of 10.2%) is 23.7% for the U.S. and 21.5% for the rest of the OECD. The second row in Table 10 says the dynamic gains are at least as large as the static gains in all cases. The dynamic gains are larger for the rest of the OECD than for the U.S.; because the rest of the OECD is less innovative, it gains more ideas than it gives.

For comparison, the static gain for the U.S. implied by the ACR formula (Arkolakis et al., 2012) is 1.1% from moving from autarky and 3% from cutting
Global destruction

**Table 10:** Gains from trade with trade-embodied idea flows

<table>
<thead>
<tr>
<th></th>
<th>50% reduction in ((\tau - 1))</th>
<th>Relative to autarky</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>U.S.</td>
<td>OECD</td>
</tr>
<tr>
<td>Static gains</td>
<td>5.5%</td>
<td>3.5%</td>
</tr>
<tr>
<td>Dynamic gains</td>
<td>6.0%</td>
<td>14.3%</td>
</tr>
<tr>
<td>Static + dynamic gains</td>
<td>11.5%</td>
<td>17.8%</td>
</tr>
</tbody>
</table>

Note: Entries show the permanent increase in consumption that yields the equivalent variation in utility as reducing tariffs from 1.50 to 1.25 (columns one and two) or reducing tariffs from 4 to 1.5 (columns three and four). The aggregate trade share at \(\tau = 4\) is about 0.4%. We use a discount rate of 1.9% and log utility.

Tariffs in half (starting from \(\tau = 1.5\)).

Clearly, our baseline model does not fall into the ACR class in which the trade elasticity is a constant parameter. In our model, trade facilitates the flow of ideas across countries. As a result, the distribution of product quality and the comparative advantage gains from trade varies endogenously with tariffs. Recall Figure 3 above, which plotted the distribution of relative quality across products for the U.S. versus the rest of the OECD. The relative quality distribution was markedly more dispersed near autarky because relative quality drifted apart when ideas did not flow as quickly between countries. As a result, the trade elasticity was only 3 near autarky, whereas it is 5 under the baseline tariff of \(\tau = 1.5\). In addition, when going from near autarky to \(\tau = 1.5\), the trade share initially leaps from 0.4% to 24.6%. The trade share on impact overshoots the new steady state trade share of 10.2% precisely because of divergent qualities near autarky. Applying the ACR formula to the trade share on impact, the ACR static gains are 9.8% for the U.S., compared to 3.5% with a trade share of only 10.2%. As qualities converge toward each other in response to higher trade flows, the trade share eventually settles down to 10.2% and the trade elasticity rises from 3 to 5.

\[^{12}\text{The ACR formula for welfare gains relative to autarky is } (1 - \text{trade share})^{-1/\text{trade elasticity}}. \text{ We use a trade elasticity of 5 based on the survey by Head and Mayer [2014].}\]
Because cutting tariffs increases idea flows across countries in our baseline model, it speeds up the common steady state growth rate in the two economies. This is the source of the large dynamic gains in our baseline model. Table 11 displays the growth effect of moving from near autarky, where the trade share is about 0.4% \((\tau \approx 4)\), to the baseline with a trade share of 10.2% \((\tau = 1.5)\). The first column in Table 11 shows that moving away from autarky to the baseline tariff of \(\tau = 1.5\) increases the growth rate by 0.47 percentage points.

**Table 11:** Change in growth from autarky with trade-embodied idea flows

<table>
<thead>
<tr>
<th>Baseline</th>
<th>Limited idea flows</th>
</tr>
</thead>
<tbody>
<tr>
<td>(\kappa = 1)</td>
<td>(\kappa = 0.1)</td>
</tr>
<tr>
<td>(\nu = 1)</td>
<td>(\nu = 1)</td>
</tr>
</tbody>
</table>

<p>| | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>0.47%</td>
<td>0.10%</td>
<td>0.45%</td>
</tr>
</tbody>
</table>

Notes: Entries are the change in the steady state growth rate in going from near-autarky (with a trade share of about 0.4%) to a tariff consistent with the observed U.S. trade share of 10.2%. The first column is the model with idea flows embodied in trade: \(\kappa = 1\) (the share of innovation building on sellers) and \(\nu = 1\) (the share of innovation building on products a country produces). The model in the second column sets \(\kappa = 0.1\) and \(\nu = 1\). The model in third column sets \(\kappa = 0.1\) and \(\nu = 0.1\). The model parameters are re-estimated in each model to fit the data moments in Table 7.

Table 11 also shows the growth effect of moving from autarky in models with limited idea flows. Column 2 shows that, when innovators primarily build upon domestically produced products rather than the productivity of sellers (some of which are foreign due to imports), moving from autarky only increases the growth rate by 0.1 percentage points. When trade has a more limited effect on idea flows, lowering tariffs has a diminished impact on growth. The third column shows the growth effect of trade liberalization when countries specialize all of their draws on the subset of products they produce. Perhaps surprisingly, lowering tariffs has about the same effect on growth as in our model with trade-embodied idea flows — raising the long run growth rate by 0.45 percentage points. The mechanism, however, is different than in our baseline model. Trade
liberalization increases growth not because trade facilitates idea flows but because specialization focuses innovation efforts on a smaller set of products.

In the model wherein idea flows are disembodied, the parameters \( z \) and \( z^* \) govern the spillover of ideas across countries. For fixed \( z \) and \( z^* \), therefore, tariffs have muted effects on welfare. The first two columns of Table 12 show the effect of moving from trade autarky to the baseline of \( \tau = 1.5 \). Here the only gains are the standard static gains from exploiting fixed comparative advantage. The static gains are 7.7% for the U.S. and 6.8% for the rest of the OECD in this disembodied model.

The last two columns of Table 12 show the effect of moving from (near) ideas autarky, where \( z \) and \( z^* \) are about 0.01, to their baseline values of \( z = .148 \) and \( z^* = .078 \). Here, moving away from ideas autarky has no effect on static gains from trade for the simple reason that tariffs do not change, but it has a large effect on the flow of ideas across countries and thus on the growth rate. The dynamic gains from moving away from ideas autarky are 23.9% for the U.S. and 55.4% for the rest of the OECD. Again, the gains are larger for the rest of world because the U.S. is more innovative.

**Table 12: Gains from trade and idea flows — disembodied spillover model**

<table>
<thead>
<tr>
<th>Relative to trade autarky</th>
<th>Relative to ideas autarky</th>
</tr>
</thead>
<tbody>
<tr>
<td>U.S.</td>
<td>OECD</td>
</tr>
<tr>
<td>Static gains</td>
<td>7.7%</td>
</tr>
<tr>
<td>Dynamic gains</td>
<td>0%</td>
</tr>
</tbody>
</table>

Note: Entries give the equivalent variation change in the present discounted value of consumption in the disembodied spillovers version of the model as a result of reducing tariffs from 4 to 1.5 (columns one and two) or increasing \( z \) and \( z^* \) from 0.01 to their baseline values of \( z = .147 \) and \( z^* = .078 \) (columns three and four). The aggregate trade share at \( \tau = 4 \) is about 0.4%. We use a discount rate of 1.9% and log utility.

---

13 Recall these are the thresholds governing which products foreign firms learn from the U.S. \((0, z)\) and which products U.S. firms learn from abroad \((z^*, 1)\).
14 Remember that the steady state of the disembodied model with \( z = .148 \) and \( z^* = .078 \) is equivalent to that in the model where idea flows are embodied in trade and \( \tau = 1.5 \).
7 Conclusion

We documented ample reallocation of exports across categories and firms in U.S. manufacturing in recent decades. Motivated by these facts, we constructed a two-country model of creative destruction and trade. In the model, foreign and domestic firms take over each other's markets more frequently when ideas flow more easily across countries. This stimulates growth in the long run under exogenous innovation rates. We find such dynamic gains from idea flow are at least as larger as the usual static gains from trade.

We see several possible directions for future research. One direction would be to explicitly incorporate frictions to reallocating workers in response to global creative destruction. These might mitigate the dynamic gains from idea flows. Another route would be to study events such as China joining the WTO. A third avenue would be to obtain more direct evidence on knowledge spillovers (e.g. the frequency of imitation of rich country producers by developing country producers, or of learning from domestic producers vs. foreign sellers in the local market). We stress that knowledge spillovers, either embodied in trade or FDI or disembodied, may be necessary to generate realistic export reallocation rates and trade elasticities. Whether trade policy or other policies have dynamic growth benefits or not, however, hinges on whether the spillovers are largely embodied or disembodied.

A final direction would be to model the arrival rates of innovation. For simplicity we held these fixed. Endogenizing innovation would allow one to study optimal innovation policy in our setting. Because of domestic knowledge spillovers, national governments may find it optimal to subsidize domestic R&D. But they might not internalize knowledge spillovers to foreign producers who build on domestic innovations. The world might need a “Global Technical Change Accord” to internalize these positive externalities, just as we need Global Climate Change agreements to internalize negative pollution externalities.
References


