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Abstract

Theories of international trade have severe difficulties in explaining why, despite i) substantial differences in factor-proportions across industries and ii) considerable cross-country differences in capital-labor ratios, the iii) the evidence for factor-proportions trade is rather weak. We propose a simple explanation of this well known finding: standard trade theories treat important forces such as the distribution of productivity within the economy as exogenous. We argue instead that the productivity allocation is endogenous and counter-balances factor-proportion differentials between countries. Consequently, comparative advantage across countries of different development levels is negligible and this is why the incentives for trade are low.

JEL: F11, F14, F41, O47

Keywords: factor-proportions trade, Heckscher-Ohlin-Vanek, macroeconomic general equilibrium models, endogenous growth, biased productivity

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1 Introduction

Standard theories in international economics predict that open borders relocate the production of labor-intensive goods to relatively labor-abundant countries. While recent micro-level studies have tendered some support for this effect (Autor et al., 2014; Acemoglu et al., 2016; Pierce and Schott, 2016)[1], the preponderance of evidence at the macro-level has not been favorable. As Figure 1 shows, the labor intensity of imports does not vary systematically across countries (Panels C and D). This lack of clear evidence is rather surprising given that a systematic variation across countries is a distinctive prediction of many theories with heterogeneous industries, including the neoclassical trade model.[2]

In this paper we provide a simple explanation for this well-known finding. Studying the neoclassical trade model that embodies the factor proportions trade (FPT) theory, we first provide overwhelming support for its *two* main assumptions. Namely, Figure 1 reveals both i) substantial differences in factor proportions across industries (Panel A) and ii) vast discrepancies in capital-labor ratios across countries (Panel B). We then address the following question: given that the core assumptions of the FPT theory are empirically valid, why does its main prediction fail so badly?

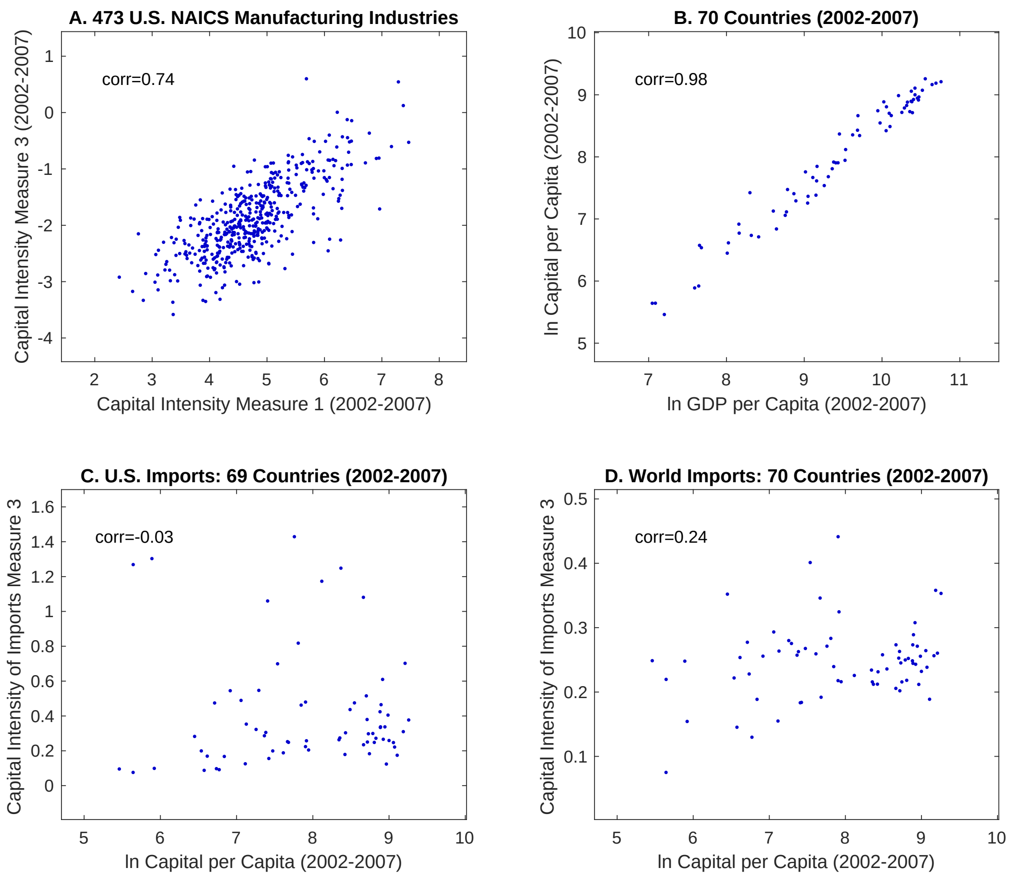
Importantly, we emphasize that altering an often overlooked assumption in the literature eliminates the gains from FPT and thus rationalizes the empirical regularities. While trade economists usually assume an exogenous allocation of productivity across intermediate goods with different labor intensities for tractability, we argue that an endogenous allocation will compensate for factor-proportion differentials.

The mechanism that suppresses the gains from trade specialization in our framework is simple and intuitive. If the technology allocation is exogenous, open borders create downward (upward)

[1]It is not the primary intention of these papers to test the standard theory. Yet, some of the evidence that they collect can be interpreted in favor of factor-proportions trade.

[2]Many theories in international trade imply that cross-country differences in capital-labor ratios should lead to pronounced trade specialization patterns. Although it is well known to trade economists that evidence in favor of this prediction is quite weak (Bowen et al., 1987; Trefler, 1995; Davis and Weinstein, 2001; Schott, 2004; Trefler and Zhu, 2010; Antràs, 2016; Feenstra, 2016), the reasons behind this outcome are not well understood. Indeed Trefler and Zhu (2010) and Caron et al. (2014) indicate that more in-depth knowledge is required in order to comprehend why this "missing trade" result arises.

Figure 1: U.S. NAICS Imports, Capital Intensities and Cross-Country Capital-Labor Ratios, 2002-2007



Notes: The cross-country data pertain to averages over the period 2002-2007. Panel A shows the relation between two different measures of the capital intensity across 473 NAICS U.S. Manufacturing Industries. Panel B shows the spread of capital-labor ratios across developed and developing countries. Panels C and D give the relation between an export-weighted measure of industry capital intensity (i.e. measure of revealed comparative advantage (RCA)) and the capital per capita ratio (ln investment per capita) across 69 developed and developing countries as well as the United States. Pearson correlations reported. Results are robust to adopting a different 6-year time period or extending the time period to, for example, 10 or 20 years. Data construction details are provided in Section A. The list of countries employed is provided in Appendix B. Table 3 provides the RCA and capital-labor ratio statistics for each country.

pressure on the relative price of labor intensive goods in the capital (labor) abundant economy. Factor price equalization within economies then demands resource reallocations toward the capital (labor) intensive goods in the capital (labor) abundant economy. As a result we observe a specialization pattern in which the capital (labor) abundant economy exports the capital (labor) intensive good.

By contrast, if the technology allocation is endogenous, returns to technology also have to be equalized across industries within the economy. Open borders create the same price pressures as before. Yet, with an endogenous technology allocation, the capital (labor) abundant economy will allocate more technology to the labor (capital) intensive good. This technology reallocation equalizes goods prices between and factor prices within economies without having capital and labor reallocate as much. This reduces the need for specialization and makes large cross-border trade flows redundant.

Our paper relates to two main literatures. First, we contribute to the literature that seeks to integrate trade dynamics into open economy macroeconomic frameworks. Findlay (1970), Mussa (1978), Ventura (1997), Cunat and Maffezzoli (2004), Antràs and Caballero (2009), Bajona and Kehoe (2010), Jin (2012), Ju et al. (2014), Zymek (2015) and Jin and Li (2017), amongst others, all integrate FPT-style assumptions into dynamic frameworks. One characteristic of these integrated macro-trade models is that they predict sizable structural breaks in the data. The breaks occur because these models imply pronounced trade specialization patterns that result from comparative advantage. Nevertheless, as Panels C and D of Figure 1 demonstrate, the empirical evidence for such predictions is rather weak.

A subset of studies, including Kongsamut et al. (2001), Acemoglu (2002), Ngai and Pissarides (2007) and Acemoglu and Guerrieri (2008) for instance, provide mechanisms that can reconcile industry heterogeneity with smooth aggregate economic outcomes in closed economy models. However, as implied, these models do not take into consideration trade specialization as a motive for output composition shifts. By reverting back to the insights of Uzawa (1961), Acemoglu (2002) and Jones (2005), we illustrate that an endogenous allocation of productivity can suppress incentives for FPT-style trade specialization and thus reconcile industry heterogeneity with stable aggregate outcomes in open economy models.[3]

Second, our paper contributes to the literature that studies the Heckscher-Ohlin-Vanek (HOV) theorem (Vanek, 1968). This theorem predicts that each country will be a net exporter of the goods

[3]On the related issue of technical change over time, Struck and Velic (2017) show that labor-augmenting technological progress is empirically plausible.

and services that use most intensively its abundant factor of production. As Davis and Weinstein (2001) note in an important paper, and as alluded to earlier, this prediction is "spectacularly at odds with the data" although the theory itself is elegant and intuitive. We argue that capital abundance is endogenous to technical progress, with productivity being allocated in a way that overcomes factor scarcity. Consequently, factor abundance does not imply a comparative advantage in goods for countries that intensively use this factor.

Our study is complementary to those works attempting to explain this "missing trade" result. Caron et al. (2014) show that the introduction of non-homothetic preferences in the context of a HOV production structure can resolve this puzzle. Our analysis is also related to the work of Struck and Velic (2016) who, using a dynamic macroeconomic model, illustrate that the gains from intra-industry trade in labor- and capital-intensive goods suppress the gains from FPT-style specialization. We follow Trefler (1993), Trefler (1995), and Morrow and Trefler (2017) in that we also emphasize factor-specific productivity. In contrast to these papers however we provide a deep foundation of the productivity allocation and show theoretically within the standard framework why the gains from FPT are small.

The remainder of the paper is structured as follows. Section 2 outlines the theory and explains the underlying mechanism of our model. In Section 3, we employ numerical simulations to illustrate the main results. Finally, Section 4 concludes.

2 Theoretical Analysis

We develop four parallel models: two exogenous and two corresponding endogenous growth models. Consider a world with two countries, Home (H) and Foreign (F), each populated by a representative consumer. Both countries produce two tradable intermediate goods in autarky whose demands are denoted by X_n where $n \in \{1, 2\}$. Each of these goods is produced with two inputs, capital (K) and labor (L). The two intermediate goods can be combined, with substitution elasticity θ, to form a final good Y. The key feature of all four models is that the capital intensity differs across intermediate goods with $\alpha_1 \neq \alpha_2$.[4,5] Section 2.1 commences with a description of the industry structure that underpins all four models. Next, section 2.2 presents two standard exogenous growth FPT models that serve as the starting point of our analysis. In this Section we derive two propositions that highlight the key conditions under which there are no gains from trade. Section 2.3 subsequently presents two extensions of these models with an endogenous allocation of productivity. Section 2.4 presents the market clearing conditions that all four models have in common.

2.1 Industry Structure

The final good Y^i used in country $i \in \{\mathrm{H}, \mathrm{F}\}$ is given by

$$Y^i \equiv \left[\gamma^{\frac{1}{\theta}}[X_1^i]^{1-\frac{1}{\theta}} + (1-\gamma)^{\frac{1}{\theta}}[X_2^i]^{1-\frac{1}{\theta}}\right]^{\frac{\theta}{\theta-1}} \tag{1}$$

where γ denotes the share of intermediate good 1 in the final good and θ is the elasticity of substitution between intermediate goods. Optimization leads to the intermediate good demands

$$X_1^i = \gamma\left(\frac{P_1^i}{P^i}\right)^{-\theta} Y^i \qquad \text{and} \qquad X_2^i = (1-\gamma)\left(\frac{P_2^i}{P^i}\right)^{-\theta} Y^i, \tag{2}$$

where P_n^i denotes the price of good n in country i. Thus, relative prices are given by

$$\left(\frac{X_1^i}{X_2^i}\frac{1-\gamma}{\gamma}\right)^{-\frac{1}{\theta}} = \frac{P_1^i}{P_2^i} \tag{3}$$

and

$$\left(\frac{X_1^i}{X_1^i\frac{P_1^i}{P^i} + X_2^i\frac{P_2^i}{P^i}}\frac{1}{\gamma}\right)^{-\frac{1}{\theta}} = \frac{P_1^i}{P^i}, \tag{4}$$

[4]We note that our models comprise elements of both Ricardian and Heckscher-Ohlin frameworks, in the sense that they feature both productivity and factor proportion differences across countries. In international macroeconomics, it is difficult to disentangle these two features as the capital stock is normally endogenously determined, ultimately depending on the exogenously allocated level of productivity. Thus differences in capital stocks and investment across countries depend on cross-country productivity differentials.

[5]Our core analysis of autarky versus free trade outcomes is conducted intratemporally. That is, we examine transitions from one zero-growth steady state (autarky) to another zero-growth steady state (free trade). Such an approach allows for a comparison with the classical Heckscher-Ohlin trade model which studies trade patterns along the cross section at a fixed point in time.

where P^i is the aggregate price level.

2.2 Exogenous Growth Setup

In this subsection, we derive an analytical solution and the underlying intuition by comparing two exogenous growth models in autarky. We later endogenize the allocation of productivity in these two models and then simulate the transition from autarky to free trade in all four models. The only difference between the two models studied in this subsection is in the exogenously given bias of technical change. Namely, in Model 1, each country produces with total factor productivity (as in a standard Heckscher-Ohlin setup),

$$Q_{n,i,t} = A_{n,i,t} K_{n,i,t}^{\alpha_n} L_{n,i,t}^{1-\alpha_n} \qquad \forall n = 1, 2, \tag{5}$$

while, in Model 2, each country produces with labor-augmenting technology (as in a long-run neoclassical model),

$$Q_{n,i,t} = K_{n,i,t}^{\alpha_n} (A_{n,i,t} L_{n,i,t})^{1-\alpha_n} \qquad \forall n = 1, 2. \tag{6}$$

where $\alpha_2 \neq \alpha_1$. The sectoral accumulation of capital is given by[6]

$$K_{n,i,t+1} = (1-\delta) K_{n,i,t} + I_{n,i,t}, \tag{7}$$

where $I_{n,i,t}$ is investment in sector n of country i and δ is the constant depreciation rate of capital. Given competitive markets, each factor of production earns its marginal revenue product

$$r_{n,i,t} = P_{n,i,t} \frac{\partial Q_{n,i,t}}{\partial K_{n,i,t}} \quad \text{and} \quad w_{n,i,t} = P_{n,i,t} \frac{\partial Q_{n,i,t}}{\partial L_{n,i,t}}. \tag{8}$$

Intersectoral mobility of capital and labor implies that factor prices are the same across sectors

$$r_{n,i,t} = r_{i,t} \quad \text{and} \quad w_{n,i,t} = w_{i,t}. \tag{9}$$

[6] In contrast to a standard Heckscher-Ohlin setup that treats capital as an endowment, capital is endogenously determined depending on the level of productivity.

The representative consumer in country i maximizes lifetime utility

$$U_{i,t} = \sum_{s=0}^{\infty} \beta^s u(C_{i,t+s}) \tag{10}$$

given the constraints

$$\sum_n w_{n,i,t} L_{n,i,t} + \sum_n r_{n,i,t} K_{n,i,t} = \sum_n P_{i,t} I_{n,i,t} + P_{i,t} C_{i,t}, \tag{11}$$

$$L_{i,t} = \sum_n L_{n,i,t}, \tag{12}$$

and equation (7). In a zero-growth steady state, the intertemporal consumption Euler equation reduces to

$$r_{i,t} = P_{i,t} \left(\frac{1}{\beta} - 1 + \delta \right). \tag{13}$$

In the case of Model 1, combining equation (13) with the capital return in equation (8) gives the capital-per effective labor ratio

$$\frac{K_{n,i,t}}{A_{n,i,t} L_{n,i,t}} = A_{n,i,t}^{\frac{\alpha_n}{1-\alpha_n}} \left(\frac{P_{i,t} \left(\frac{1}{\beta} - 1 + \delta \right)}{\alpha_n P_{n,i,t}} \right)^{\frac{1}{\alpha_n - 1}}. \tag{14}$$

In the case of Model 2, solving for the capital-per effective labor ratio yields

$$\frac{K_{n,i,t}}{A_{n,i,t} L_{n,i,t}} = \left(\frac{P_{i,t} \left(\frac{1}{\beta} - 1 + \delta \right)}{\alpha_n P_{n,i,t}} \right)^{\frac{1}{\alpha_n - 1}}. \tag{15}$$

Proposition 1. *In Model 1, the sectoral capital per effective-labor ratio depends on the level of development and on the sector's relative price. By contrast, in Model 2 this ratio only depends on the relative price.* ■

In Model 1, using equations (8), (9) and (14) yields

$$\frac{P_{n,i,t}}{P_{\neg n,i,t}} \frac{\left(\frac{P_{\neg n,i,t}}{P_{i,t}}\right)^{\frac{\alpha_{\neg n}}{\alpha_{\neg n}-1}}}{\left(\frac{P_{n,i,t}}{P_{i,t}}\right)^{\frac{\alpha_n}{\alpha_n-1}}} = \frac{1-\alpha_{\neg n}}{1-\alpha_n} \frac{\left(\frac{\frac{1}{\beta}-1+\delta}{\alpha_{\neg n}}\right)^{\frac{\alpha_{\neg n}}{\alpha_{\neg n}-1}}}{\left(\frac{\frac{1}{\beta}-1+\delta}{\alpha_n}\right)^{\frac{\alpha_n}{\alpha_n-1}}} \frac{A_{\neg n,i,t}^{\frac{1}{1-\alpha_{\neg n}}}}{A_{n,i,t}^{\frac{1}{1-\alpha_n}}}. \tag{16}$$

Equation (16) shows that relative sectoral prices only depend on the constant exogenous parameters δ, β, α_n, $\alpha_{\neg n}$, and productivity $A_{i,t}$. In Model 2, combining the first-order equations yields

$$\frac{P_{n,i,t}}{P_{\neg n,i,t}} \frac{\left(\frac{P_{\neg n,i,t}}{P_{i,t}}\right)^{\frac{\alpha_{\neg n}}{\alpha_{\neg n}-1}}}{\left(\frac{P_{n,i,t}}{P_{i,t}}\right)^{\frac{\alpha_n}{\alpha_n-1}}} = \frac{1-\alpha_{\neg n}}{1-\alpha_n} \frac{\left(\frac{\frac{1}{\beta}-1+\delta}{\alpha_{\neg n}}\right)^{\frac{\alpha_{\neg n}}{\alpha_{\neg n}-1}}}{\left(\frac{\frac{1}{\beta}-1+\delta}{\alpha_n}\right)^{\frac{\alpha_n}{\alpha_n-1}}} \frac{A_{\neg n,i,t}}{A_{n,i,t}}. \tag{17}$$

Proposition 2. *In Model 1, the relative price of capital- to labor-intensive goods is equal across countries in the special case that* $A_{\neg n,i,t}^{\frac{1}{1-\alpha_{\neg n}}}/A_{n,i,t}^{\frac{1}{1-\alpha_n}} = A_{\neg n,\neg i,t}^{\frac{1}{1-\alpha_{\neg n}}}/A_{n,\neg i,t}^{\frac{1}{1-\alpha_n}}$. *By contrast, in Model 2, the relative price of capital- to labor-intensive goods is equal across countries in the special case that* $A_{\neg n,i,t}/A_{n,i,t} = A_{\neg n,\neg i,t}/A_{n,\neg i,t}$. ■

In a standard Heckscher-Ohlin setup, the focus is usually not on the bias of technical change. These types of models often make the over-simplifying assumption that total factor productivity is evenly allocated across industries, i.e. that $A_{\neg n,i,t} = A_{n,i,t}$ in the context of Model 1 and that $A_{\neg n,i,t}^{1-\alpha_{\neg n}} = A_{n,i,t}^{1-\alpha_n}$ in the context of Model 2. We will now show that this oversimplifying assumption generates large gains from trade in this class of models. Furthermore, we provide a simple endogenous growth foundation that directly leads to the two special cases of Proposition 2.

2.3 Endogenous Growth Setup

In Models 3 and 4, that we now introduce, we endogenize the productivity allocation within the economy. Model 3 is the endogenous growth version of Model 1, while Model 4 is the endogenous growth version of Model 2. To model all factors symmetrically, we assume that aggregate productivity in country i, A_i, is the sum of sectoral productivities,

$$A_{i,t} = A_{1,i,t} + A_{2,i,t}. \tag{18}$$

This constraint is a linear version of the technology menu constraint in Jones (2005). Allowing the consumer to optimize with respect to $A_{1,i,t}$ and $A_{2,i,t}$ then leads to the cross-industry equalization of marginal products of technology, i.e. $\phi_{i,n,t} = \phi_{i,\neg n,t}$ where $\phi_{i,n,t} = P_{n,i,t}\frac{\partial Q_{n,i,t}}{\partial A_{n,i,t}}$.

2.4 Market Clearing

In autarky, domestic intermediate goods consumption must equal domestic intermediate goods supply,

$$X_n^i = Q_n^i. \tag{19}$$

By contrast, under free trade, world intermediate goods consumption must equal world intermediate goods supply,

$$\sum_i X_n^i = \sum_i Q_n^i, \tag{20}$$

where we assume domestic and foreign prices are equalized as a result of free trade i.e. $P_n^i = P_n^{\neg i}$. To close the free trade models, we assume that there is zero net trade, consistent with a long-run budget constraint. Formally,

$$\sum_{n=1,2} \frac{P_n}{P} X_n^i = \sum_{n=1,2} \frac{P_n}{P} Q_n^i. \tag{21}$$

We study the transition from autarky to free trade in all four models.

3 Numerical Analysis

In this section we numerically explore the implications of our four models. We stipulate once again that the four models are evaluated across states of autarky and free trade.

3.1 Parameter Calibration

We do not expect these over-simplified models to precisely match the real world data. Instead we employ simulations to illustrate some basic theoretical results. Table 1 displays the chosen parameter values. Referring to this common set of parameters across models, we firstly set the capital intensities of intermediate goods 1 and 2, α_1 and α_2, to 0.56 and 0.33 respectively (i.e. $\alpha_1 > \alpha_2$). These values are consistent with the U.S. data estimates provided in Table 4. The table divides tradable manufacturing goods (i.e. industries) into two relatively stable fractions, a composite capital-intensive tradable good (1) and a composite labor-intensive tradable good (2). Consistent with Table 4 again, intermediate good 1's share in the final good, γ, is set equal to 0.5.

Table 1: Simulation Parameters for Main Result

common	$\gamma = 0.5,\ \theta = 0.1,\ \alpha_1 = 0.56,\ \alpha_2 = 0.33,\ \beta = 0.97,\ \delta = 0.15,\ L_H = 1,\ L_F = 1$
Model 1	$A_H = 1.4,\ A_F = 1,\ A_{1,H} = 0.7,\ A_{2,H} = 0.7,\ A_{1,F} = 0.5,\ A_{2,F} = 0.5$ $K_H = 2.6,\ K_F = 1.5$
Model 3	$A_H = 1.4,\ A_F = 1$ $K_H = 2.6,\ K_F = 1.5$
Model 2	$A_{1,H}^{1-\alpha 1} + A_{2,H}^{1-\alpha 2} = 1.4,\ A_{1,F}^{1-\alpha 1} + A_{2,F}^{1-\alpha 2} = 1,\ A_{1,H}^{1-\alpha 1} = 0.7,\ A_{2,H}^{1-\alpha 2} = 0.7,\ A_{1,F}^{1-\alpha 1} = 0.5,\ A_{2,F}^{1-\alpha 2} = 0.5$ $K_H = 2.6,\ K_F = 1.5$
Model 4	$A_H = 1.4,\ A_F = 1$ $K_H = 2.6,\ K_F = 1.5$

The elasticity of substitution between intermediate goods, θ, is assigned the value 0.1. Given the complementarity found empirically between capital and labor factor inputs in production (Antràs, 2004; Chirinko, 2008; Chirinko et al., 2011; Oberfield and Raval, 2014; Herrendorf et al., 2015; Chirinko and Mallick, 2017), it is natural to assume complementarity between capital- and labor-intensive intermediate good inputs in final good production in our setup. As shown in Table 4, the consolidated capital- and labor-intensive goods largely overlap with durable and nondurable goods categories. Indeed, Cashin and Unayama (2016) find that durable and nondurable goods exhibit strong complementarity, with an estimated intratemporal elasticity of substitution of less than 0.21. Others reaching similar conclusions include Pakos (2011) and Cashin (2016). More generally, intermediate goods featuring different production characteristics tend to be complements.

We normalize the population in Home (developed) and Foreign (developing) to unity, i.e. $L_H = 1$ and $L_F = 1$. Next, we set $A_H = 1.4$ and $A_F = 1$. This choice is close to the maximum productivity differential in which both countries still produce both goods even when they are specialized under free trade across all four models. This parameterization is motivated by findings in a related literature suggesting significant discrepancies in cross-country productivity levels e.g. see Hall and Jones (1999) amongst others. Lastly, we assume a relatively standard value for the discount factor β of 0.97, while the capital depreciation rate is set equal to 0.15. We first simulate the exogenous growth models in autarky to back out the aggregate capital stocks. We then take these capital stocks as given and simulate the four models without endogenous capital formation. This procedure helps us make the four models more comparable.[7] For the exogenous growth models, we assume that the allocation of total factor productivity is even across industries, i.e. $A_{\neg n,i,t} = A_{n,i,t}$ in Model 1 and $A_{\neg n,i,t}^{1-\alpha_{\neg n}} = A_{n,i,t}^{1-\alpha_n}$ in Model 2.

3.2 Simulation Results

Figure 2 and Table 2 illustrate the effects of moving from a state of autarky to a state of free trade across all four models. Figures 3 and 4 provide robustness checks in the cases of i) a higher elasticity of substitution between intermediate goods and ii) a lower productivity differential between countries. Panels A-D show relative productivity while Panels E and F show relative prices and global trade, respectively. In the state of autarky (time 1-5), Panels A and B of Figure 2 show us, in light of Proposition 2, that relative prices must vary across countries. Panel E confirms that

[7] Otherwise the models would have different capital stocks due to different allocations of productivity within the economy. Nonetheless, this procedure does not affect at all our main result that the gains from trade are low when there is an endogenous productivity allocation.

the price of the capital-intensive good is lower in capital-abundant Home than in labor-abundant Foreign in Models 1 and 2.

In autarky, the patterns are qualitatively similar in Model 3. However, there are quantitative differences. Panel C shows that the relative price differential across countries is smaller. The reason can be found in the degree of complementarity between intermediates and the induced endogenous productivity allocation, as Robustness Test A in Figure 3 illustrates. The intuition is the following: since the degree of substitution in Figure 2 is rather low (in contrast to Robustness Test A), it is optimal to allocate more productivity to the more labor-intensive good which is more difficult to produce because of the relative scarcity of labor. Hence, the allocation of productivity brings down the relative price of labor. If the substitutability between goods is higher (as in Robustness Test A), then more productivity will be allocated to the relatively capital-intensive good (Panel C of Figure 3).

In autarky, the behavior is different in Model 4. The reason can be understood by focusing on Propositions 1 and 2. Because the capital-per-effective labor ratio in each industry does not change with sectoral productivity (Proposition 1), the relative goods price does not change across income levels as long as the allocation of labor productivity across industries remains constant (Proposition 2). This allocation remains constant, as, in contrast to Model 3, cross-country differences in productivity are proportional to the differences in capital stocks.

Trade liberalization (time 6-10) in Models 1 and 2 induces strong specialization patterns across the two regions. This is revealed by Panel F of Figure 2 which shows that the world trade to GDP ratio goes from zero to more than 50% in both models. By contrast, Panel C reveals for Model 3 that, once we move to the free trade equilibrium, productivity is allocated in a way that is consistent with the special cases highlighted in Proposition 2. That is, the incentives for trade are eradicated because the productivity allocation already equalizes relative prices and hence the world trade to GDP ratio is nearly zero as Panel F shows. Figures 3 and 4 under the assumptions of a higher elasticity of $\theta = 1.1$ and a smaller productivity differential $A_H = 1.2$ and $A_F = 1$ confirm these results.

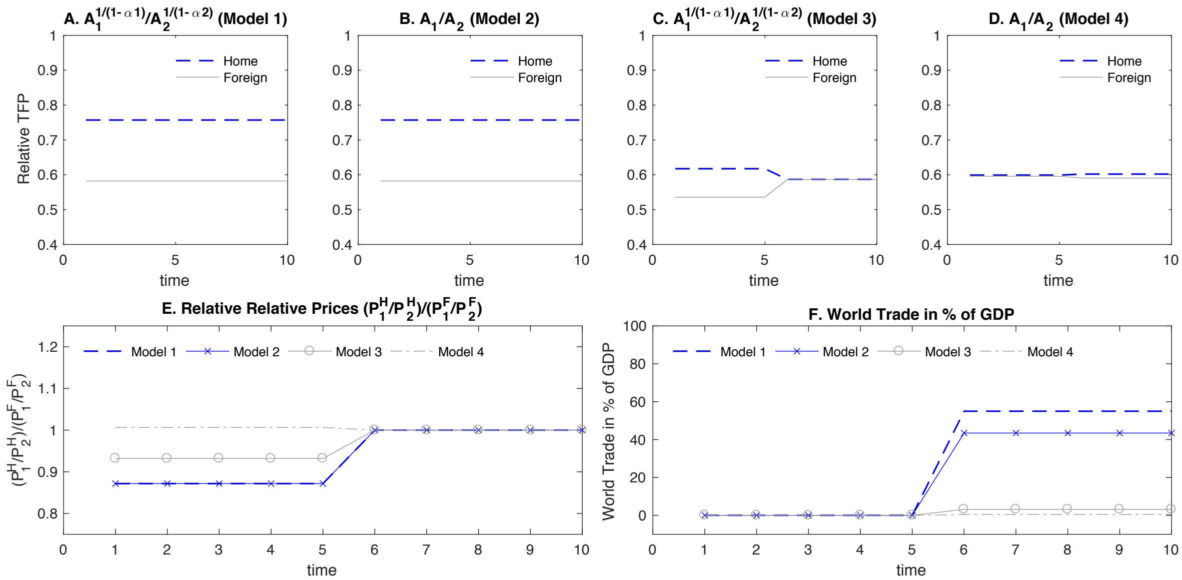
What is the intuition behind this result? The mechanism that suppresses the gains from trade specialization in Model 3 is simple and intuitive. If the technology allocation is exogenous, open borders create downward pressure on the relative price of labor-intensive goods in the capital abundant economy and upward pressure on the relative price of the same good in the labor-abundant economy. Factor price equalization within economies then demands capital and labor reallocations toward the capital (labor) intensive goods in the capital (labor) abundant economy.

If the technology allocation is endogenous, returns to technology also have to be the same across industries. Open borders create the same price pressures as in the exogenous technology model. Yet, in the endogenous technology model, the capital (labor) abundant economy will allocate more technology to the labor (capital) intensive good. This technology reallocation equalizes factor prices within countries without having capital and labor reallocate. In other words, the technology reallocation offsets the needs for specialization and therefore makes trade redundant.

By contrast, in Model 1, there is a difference in relative prices across countries that translates into a comparative advantage. Thus, those countries with a lower relative price of capital-intensive goods start exporting these goods in exchange for labor-intensive goods. Similarly, countries with a higher relative price of capital-intensive goods start exporting labor-intensive goods and importing capital-intensive goods.

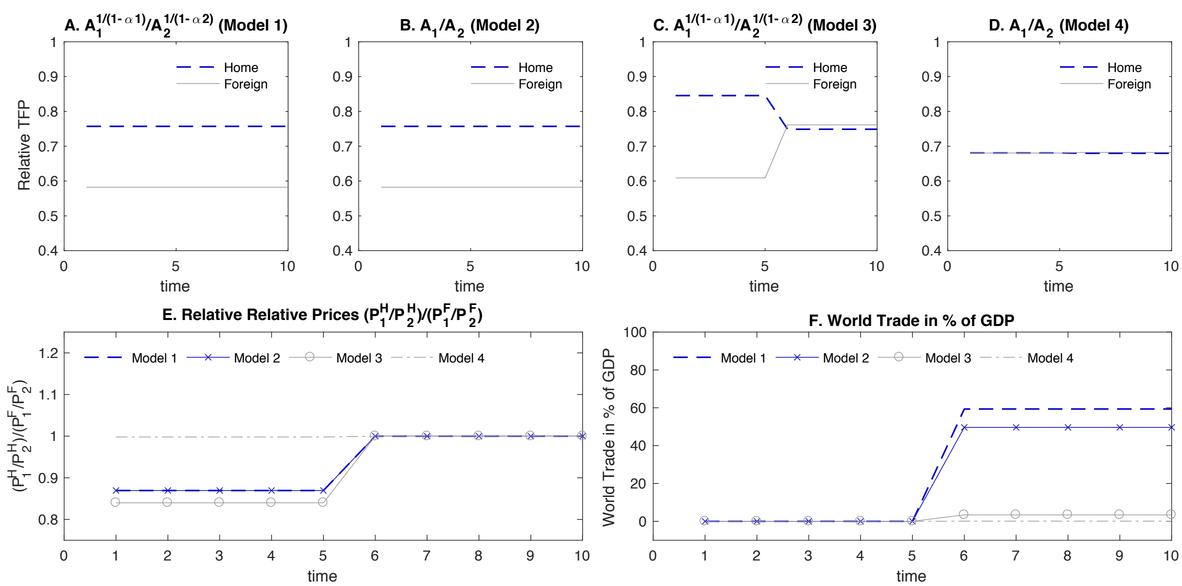
In Model 4, there is no relative goods price difference between countries in autarky and this is why there is no incentive for specialization, and hence trade, when the countries open borders. By contrast the logic behind the incentives for trade in Model 2 are the same as in Model 1.

Figure 2: Main Result



Notes: Time 1-5 shows the equilibrium in autarky. Time 6-10 shows the equilibrium under free trade. The top four Panels, A, B, C and D show allocation of technology across industries and countries. The bottom two Panels, E and F, show relative prices across countries and models as well as the amount of trade respectively.

Figure 3: Robustness Test A: Higher Intermediate Goods Elasticity ($\theta = 1.1$)



Notes: Time 1-5 shows the equilibrium in autarky. Time 6-10 shows the equilibrium under free trade. The top four Panels, A, B, C and D show allocation of technology across industries and countries. The bottom two Panels, E and F, show relative prices across countries and models as well as the amount of trade respectively.

4 Conclusions

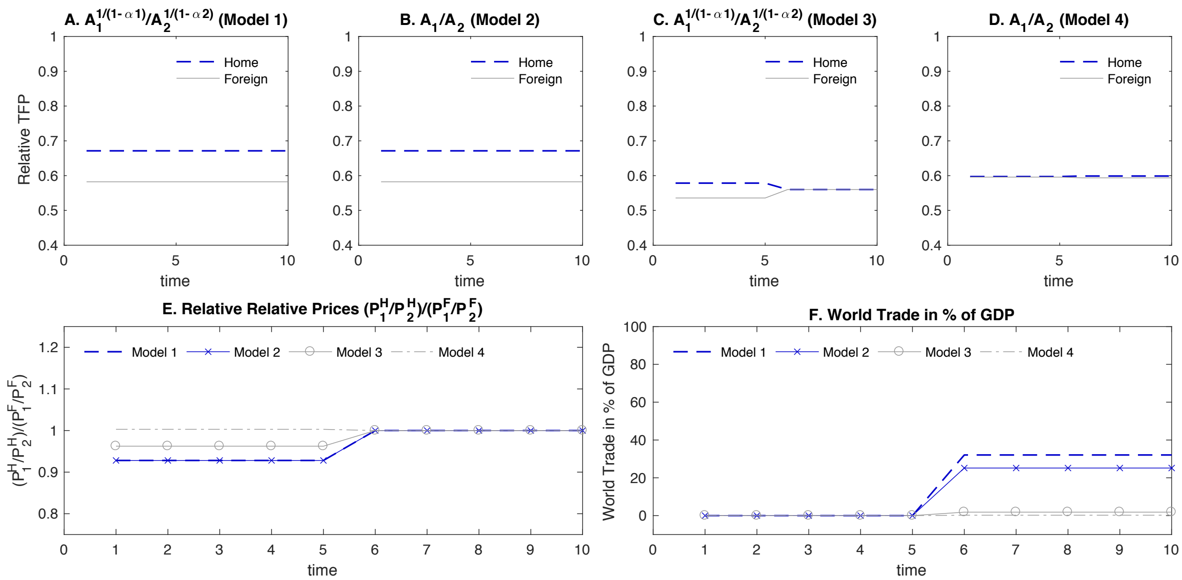
Two-country models with heterogeneous industries predict that gains from factor proportions trade (FPT) lead to a strong relation between capital-labor ratios and the capital-intensity of imports

Table 2: Simulation Results

		Model 1		Model 2		Model 3		Model 4	
		Autarky	*Free Trade*	*Autarky*	*Free Trade*	*Autarky*	*Free Trade*	*Autarky*	*Free Trade*
Main result									
Home	P_1/P_2	0.79	0.83	0.79	0.83	0.89	0.91	0.90	0.90
	L_1/L_2	0.53	1.35	0.53	1.35	0.59	0.57	0.60	0.60
	K_1/K_2	1.38	3.50	1.38	3.50	1.52	1.48	1.55	1.56
	TFP_1/TFP_2	1.00	1.00	1.00	1.00	0.90	0.87	0.88	0.89
Foreign	P_1/P_2	0.91	0.83	0.91	0.83	0.95	0.91	0.90	0.90
	L_1/L_2	0.60	0.06	0.60	0.06	0.63	0.66	0.60	0.59
	K_1/K_2	1.56	0.14	1.56	0.14	1.62	1.70	1.54	1.53
	TFP_1/TFP_2	1.00	1.00	1.00	1.00	0.96	1.00	1.01	1.01
Robustness Test A: $\theta = 1.1$									
Home	P_1/P_2	0.79	0.83	0.79	0.83	0.75	0.79	0.84	0.84
	L_1/L_2	0.69	1.86	0.69	1.86	0.70	0.65	0.68	0.68
	K_1/K_2	1.78	4.81	1.78	4.81	1.80	1.69	1.76	1.76
	TFP_1/TFP_2	1.00	1.00	1.00	1.00	1.06	0.99	0.94	0.94
Foreign	P_1/P_2	0.91	0.83	0.91	0.83	0.89	0.79	0.84	0.84
	L_1/L_2	0.67	0.07	0.67	0.07	0.67	0.76	0.68	0.68
	K_1/K_2	1.73	0.17	1.73	0.17	1.74	1.96	1.76	1.76
	TFP_1/TFP_2	1.00	1.00	1.00	1.00	1.02	1.15	1.09	1.09
Robustness Test B: : $A_H = 1.2$, $A_F = 1.0$									
Home	P_1/P_2	0.84	0.87	0.84	0.87	0.92	0.93	0.90	0.90
	L_1/L_2	0.56	1.02	0.56	1.02	0.61	0.60	0.60	0.60
	K_1/K_2	1.46	2.63	1.46	2.63	1.57	1.54	1.54	1.55
	TFP_1/TFP_2	1.00	1.00	1.00	1.00	0.92	0.91	0.94	0.94
Foreign	P_1/P_2	0.91	0.87	0.91	0.87	0.95	0.93	0.90	0.90
	L_1/L_2	0.60	0.25	0.60	0.25	0.63	0.64	0.60	0.59
	K_1/K_2	1.56	0.66	1.56	0.66	1.62	1.66	1.54	1.53
	TFP_1/TFP_2	1.00	1.00	1.00	1.00	0.96	0.98	1.01	1.01

Notes: The table shows the simulation results for all four models und both autarky and free trade. $TFP_1/TFP_2 = A_1/A_2$ in the case of odels 1 and 3, whereas $TFP_1/TFP_2 = A_1^{1-\alpha 1}/A_2^{1-\alpha 2}$ in models 2 and 4.

Figure 4: Robustness Test B: Lower Productivity Differential ($A_H = 1.2$, $A_F = 1.0$)



Notes: Time 1-5 shows the equilibrium in autarky. Time 6-10 shows the equilibrium under free trade. The top four Panels, A, B, C and D show allocation of technology across industries and countries. The bottom two Panels, E and F, show relative prices across countries and models as well as the amount of trade respectively.

across countries. Yet, world trade data indicate that this relation is rather weak. In this paper, we provide a simple explanation for this well known finding. We contend that appropriately accounting for the distribution of productivity within the economy completely alters the predictions of standard theories and subsequently allows us to rationalize the empirical evidence.

Our analysis demonstrates that changing a seemingly innocent assumption of the standard FPT theory triggers an important interaction that eliminates the gains from FPT-style trade specialization. The assumption pertains to the treatment of the distribution of productivity within the economies. Standard models typically treat the distribution as exogenous and often even make the over-simplifying assumption of an even allocation across industries.

Instead, we assume that the allocation of productivity within the economy is endogenous. Under a variety of assumptions we then show that an endogenous distribution offsets factor-proportions differentials across countries and thereby equalizes relative prices of intermediate goods such that the incentives for trade are greatly reduced. In comparison, cross-country relative price discrepancies are present in standard FPT models. Such differences generate gains from trade, and thus lead to predictions of pronounced trade specialization patterns in the class of FPT models.

References

Acemoglu, Daron (2002), "Directed Technical Change," *Review of Economic Studies* 69, 781-809.

Acemoglu, Daron, David Autor, David Dorn, Gordon H. Hanson and Brendan Price (2016), "Import Competition and the Great U.S. Employment Sag of the 2000s," *Journal of Labor Economics* 34, S141-S198.

Acemoglu, Daron and Veronica Guerrieri (2006), "Capital Deepening and Non-Balanced Economic Growth," NBER Working Paper No. 12475.

Acemoglu, Daron and Veronica Guerrieri (2008), "Capital Deepening and Non-Balanced Economic Growth," *Journal of Political Economy* 116, 467-498.

Allen, Treb and Costas Arkolakis (2016), "Elements of Advanced International Trade," Graduate Trade Notes.

Antràs, Pol (2004), "Is the U.S. Aggregate Production Function Cobb-Douglas? New Estimates of the Elasticity of Substitution," *B.E. Journal of Macroeconomics* 4, 1-36.

Antràs, Pol (2016), *Global Production: Firms, Contracts, and Trade Structure*, Princeton, NJ: Princeton University Press.

Antràs, Pol and Ricardo J. Caballero (2009), "Trade and Capital Flows: A Financial Frictions Perspective," *Journal of Political Economy* 117, 701-744.

Autor, David, David Dorn, Gordon H. Hanson and Jae Song (2014), "Trade Adjustment: Worker-Level Evidence," *Quarterly Journal of Economics* 129, 1799-1860.

Bajona, Claustre and Timothy Kehoe (2010), "Trade, Growth, and Convergence in a Dynamic Heckscher-Ohlin Model," *Review of Economic Dynamics* 13, 487-513.

Becker, Randy, Wayne Gray and Jordan Marvakov (2009), *NBER-CES Manufacturing Industry Database*, National Bureau of Economic Research.

Bowen, Harry, Edward Leamer and Leo Sveikauskas (1987), "Multicountry, Multifactor Tests of the Factor Abundance Theory," *American Economic Review* 77, 791-809.

Caron, Justin, Thibault Fally and James R. Markusen (2014), "International Trade Puzzles: A Solution Linking Production and Preferences," *Quarterly Journal of Economics* 129, 1501-1552.

Caselli, Francesco and James Feyrer (2007), "The Marginal Product of Capital," *Quarterly Journal of Economics* 122, 535-568.

Cashin, David (2016), "The Household Expenditure Response to a Consumption Tax Increase," Board of Governors of the Federal Reserve System Finance and Economics Discussion Series.

Cashin, David and Takashi Unayama (2016), "Measuring Intertemporal Substitution in Consumption: Evidence From a VAT Increase in Japan," *Review of Economics and Statistics* 98, 285-297.

Chirinko, Robert S. (2008), "σ: The Long and Short of It," *Journal of Macroeconomics* 30, 671-686.

Chirinko, Robert S., Steven M. Fazzari and Andrew P. Meyer (2011), "A New Approach to Estimating Production Function Parameters: The Elusive Capital-Labor Substitution Elasticity," *Journal of Business and Economic Statistics* 29, 587-594.

Chirinko, Robert S. and Debdulal Mallick (2017), "The Substitution Elasticity, Factor Shares, Long-Run Growth, and the Low-Frequency Panel Model," *American Economic Journal: Macroeconomics* 9, 225-253.

Courant, Paul N. and Alan V. Deardorff (1992), "International Trade with Lumpy Countries," *Journal of Political Economy* 100, 198-210.

Cunat, Alejandro and Marco Maffezzoli (2004), "Neoclassical Growth and Commodity Trade," *Review of Economic Dynamics* 7, 707-736.

Davis, Donald R. and David E. Weinstein (2001), "An Account of Global Factor Trade," *American Economic Review* 91, 1423-1453.

Feenstra, Robert C. (2016), *Advanced International Trade: Theory and Evidence*, Second Edition, Princeton, NJ: Princeton University Press.

Findlay, Ronald (1970), "Factor Proportions and Comparative Advantage in the Long Run," *Journal of Political Economy* 78, 27-34.

Gollin, Douglas (2002), "Getting Income Shares Right," *Journal of Political Economy* 110, 458-474.

Hall, Robert E. and Charles I. Jones (1999), "Why Do Some Countries Produce So Much More Output Per Worker Than Others?," *Quarterly Journal of Economics* 114, 83-116.

Herrendorf, Berthold, Christopher Herrington and Ákos Valentinyi (2015), "Sectoral Technology and Structural Transformation," *American Economic Journal: Macroeconomics* 7, 104-133.

Hunter, Linda C. and James R. Markusen (1988), "Per-Capita Income as a Determinant of Trade," in R. C. Feenstra (Ed.), Empirical Methods for International Trade, Cambridge: MIT Press.

Jin, Keyu (2012), "Industrial Structure and Capital Flows," *American Economic Review* 102, 2111-2146.

Jin, Keyu and Nan Li (2017), "International Transmission With Heterogeneous Sectors," *American Economic Journal: Macroeconomics* forthcoming.

Jones, Charles I. (2005), "The Shape of Production Functions and the Direction of Technical Change," *Quarterly Journal of Economics* 120, 517-549.

Ju, Jiandong, Kang Shi and Shang-Jin Wei (2014), "On the Connections Between Intra-temporal and Intertemporal Trades," *Journal of International Economics* 92 Supplement 1, S36-S51.

Kongsamut, Piyabha, Sergio Rebelo and Danyang Xie (2001), "Beyond Balanced Growth," *Review of Economic Studies* 68, 869-882.

Lane, Philip and Gian Maria Milesi-Ferretti (2012), "External Adjustment and the Global Crisis," *Journal of International Economics* 88, 252-265.

Lawrence, Robert Z. (2015), "Recent Declines in Labor's Share in US Income: A Preliminary Neoclassical Account," NBER Working Paper No. 21296.

Morrow, M. Peter and Trefler, Daniel (2017), "Endowments, Skill-Biased Technology, and Factor Prices: A Unified Approach to Trade," NBER Working Paper No. 24078.

Mussa, Michael (1978), "Dynamic Adjustment in the Heckscher-Ohlin-Samuelson Model," *Journal of Political Economy* 86, 775-791.

Ngai, Liwa R. and Christopher A. Pissarides (2007), "Structural Change in a Multisector Model of Growth," *American Economic Review* 97, 429-443.

Oberfield, Ezra and Devesh Raval (2014), "Micro Data and Macro Technology," NBER Working Paper No. 20452.

Ogaki, Masao and Carmen M. Reinhart (1998), "Measuring Intertemporal Substitution: The Role of Durable Goods," *Journal of Political Economy* 106, 1078-1098.

Pakos, Michal (2011), "Estimating Intertemporal and Intratemporal Substitutions When Both Income and Substitution Effects Are Present: The Role of Durable Goods," *Journal of Business and Economic Statistics* 29, 439-454.

Pierce, Justin R. and Peter K. Schott (2016), "The Surprisingly Swift Decline of U.S. Manufacturing Employment," *American Economic Review* 106, 1632-1662.

Romalis, John (2004), "Factor Proportions and the Structure of Commodity Trade," *American Economic Review* 94, 67-97.

Schott, Peter K. (2004), "Across-Product Versus Within-Product Specialization in International Trade," *Quarterly Journal of Economics* 119, 647-678.

Schott, Peter K. (2008), "The Relative Sophistication of Chinese Exports," *Economic Policy* 23, 5-49.

Struck, Clemens and Adnan Velic (2016), "Competing Gains From Trade," Trinity College Dublin, Department of Economics, TEP Working Paper No. 1116.

Struck, Clemens and Adnan Velic (2017), "To Augment Or Not To Augment? A Conjecture On Asymmetric Technical Change," Trinity College Dublin, Department of Economics, TEP Working Paper No. 0117.

Trefler, Daniel (1993), "International Factor Price Differences: Leontief Was Right!," *Journal of Political Economy* 101, 961-987.

Trefler, Daniel (1995), "The Case of the Missing Trade and Other Mysteries," *American Economic Review* 85, 1029-1046.

Trefler, Daniel and Susan C. Zhu (2010), "The Structure of Factor Content Predictions," *Journal of International Economics* 82, 195-207.

Uzawa, Hirofumi (1961), "Neutral Inventions and the Stability of Growth Equilibrium," *Review of Economic Studies* 28, 117-124.

Vanek, Jaroslav (1968), "The Factor Proportions Theory: The N-Factor Case," *Kyklos* 21, 749-754.

Ventura, Jaume (1997), "Growth and Interdependence," *Quarterly Journal of Economics* 112, 57-84.

Zymek, Robert (2015), "Factor Proportions and the Growth of World Trade," *Journal of International Economics* 95, 42-53.

Appendices

A Basic Empirical Evidence

This section is an excerpt from Struck and Velic (2016) which contains more details on the data construction as well as additional robustness tests. To obtain measures of inter-industry trade, we construct two disaggregated international trade datasets - one based on U.S. trade data and the other based on World trade data. In particular, the first set combines the U.S. 6-digit North American Industry Classification System (NAICS) trade data of Schott (2008) with Census trade data in order to yield the extended sample period 1989-2008. Meanwhile, the second set uses the product-level BACI World trade data of the CEPII over the period 1995-2006.[8] We rectangularize the raw datasets by treating any missing values as zero import or export flows. For the latter dataset, we transform the 6-digit HS-1992 data into 4-digit Standard Industrial Classification (SIC) categories using a concordance from the World Bank. Subsequently, we are able to link both datasets to the NBER-CES Manufacturing Industry database (Becker et al. (2009)) which includes subsectoral information on variables such as employment, payroll, investment, capital stock, and value added.[9] This completes the datasets for the purposes of calculating different indices of inter-industry trade dynamics.

We capture such trade specialization in capital and labor-intensive manufacturing industries across countries by computing trade-weighted measures of revealed comparative advantage. More precisely, for country i at time t, we define revealed comparative advantage (RCA) in capital-intensive goods as the trade-weighted capital intensity of exports

$$RCA_{i,t} = \sum_{z \in Z} \frac{x_{i,z,t}}{X_{i,t}} k_{z,t} \tag{A.1}$$

where $x_{i,z,t}$ denotes the exports of country i in industry $z \in Z$ to the U.S./World in period t, $X_{i,t}$ represents the total exports of country i to the U.S./World in period t, and $k_{z,t}$ is the capital intensity of industry z in period t. Given the trade-weighted nature of the measure, we note that the index is insensitive to the digit level of the trade data. Furthermore, we point out that this measure of trade specialization derives directly from the theory, which we outline in section 2.1. As evident from equation (A.1), we make the standard assumption that industry factor intensities are the same across countries, thus allowing factor intensity to be consistently ranked using factor share data for just one country, namely the U.S.. We use U.S. capital intensity data both for reasons of availability and attractiveness given the size and diversity of the country's industrial economy. Following the literature, we employ three different measures of capital intensity

[8] At the industry/product-level, NAICS data gauge exports by countries to the U.S., while BACI data which are drawn on UN COMTRADE data reflect exports of countries to the rest of the world.

[9] Note that the NBER-CES Manufacturing data are available at the 6-digit NAICS level consisting of 473 industries and the 4-digit SIC level consisting of 459 industries. After these data are paired with the corresponding trade data, we are left with 389 NAICS and 386 SIC common manufacturing industries.

Table 3: Revealed Comparative Advantage (RCA) and Cross-Country Capital-Labor Ratios, 2002-2007 Averages

country	RCA^{US}	RCA^{W}	$\frac{capital}{capita}$	country	RCA^{US}	RCA^{W}	$\frac{capital}{capita}$	country	RCA^{US}	RCA^{W}	$\frac{capital}{capita}$
ARG	0.70	0.40	7.54	GBR	0.38	0.26	8.71	NZL	0.23	0.27	8.67
AUS	0.25	0.26	9.06	GHA	1.27	0.22	5.64	PAK	0.10	0.15	5.92
AUT	0.26	0.23	9.00	GRC	0.52	0.25	8.70	PER	0.49	0.29	7.06
BEL	0.46	0.29	8.90	GTM	0.10	0.23	6.74	PHL	0.28	0.35	6.45
BGD	0.08	0.08	5.64	HKG	0.12	0.21	8.96	POL	0.20	0.22	7.94
BGR	0.46	0.24	7.85	HRV	0.27	0.22	8.35	PRT	0.48	0.24	8.55
BLR	1.43	0.27	7.76	HUN	0.26	0.23	8.34	RUS	0.82	0.28	7.81
BRA	0.32	0.28	7.26	IDN	0.17	0.25	6.62	SGP	0.31	0.36	9.19
CAN	0.34	0.27	8.95	IND	0.20	0.22	6.54	SLV	0.17	0.19	6.84
CHE	0.22	0.24	9.07	IRL	0.38	0.35	9.26	SVK	0.30	0.23	8.43
CHL	0.48	0.44	7.90	ISL	0.17	0.19	9.11	SVN	0.25	0.22	8.81
CHN	0.16	0.18	7.42	ISR	0.18	0.21	8.42	SWE	0.34	0.24	8.89
CMR	1.30	0.25	5.89	ITA	0.25	0.20	8.72	THA	0.20	0.27	7.47
COL	0.55	0.28	7.29	JPN	0.27	0.25	8.83	TUN	1.06	0.18	7.41
CRI	0.25	0.35	7.67	KEN	0.10	0.25	5.46	TUR	0.25	0.19	7.68
CYP	0.44	0.26	8.49	KOR	0.33	0.27	8.89	UKR	0.35	0.26	7.13
CZE	0.18	0.22	8.74	LBN	0.19	0.26	7.61	URY	0.31	0.26	7.38
DEU	0.30	0.25	8.73	LKA	0.09	0.13	6.77	USA	-	0.26	9.16
DNK	0.27	0.24	8.92	LTU	1.17	0.23	8.12	VNM	0.09	0.15	6.57
DOM	0.13	0.15	7.11	LVA	1.25	0.21	8.37	ZAF	0.29	0.26	7.36
EGY	0.47	0.28	6.71	MAR	0.54	0.26	6.92				
ESP	0.40	0.26	8.99	MEX	0.22	0.22	7.90				
EST	1.08	0.21	8.66	MYS	0.26	0.32	7.92				
FIN	0.42	0.25	8.88	NLD	0.61	0.31	8.92				
FRA	0.30	0.25	8.79	NOR	0.70	0.26	9.21				

Notes: The capital-labor ratio is given by the *ln* of investment per capita ratio. RCA^{W} denotes the Measure 3 of Revealed Comparative Advantage (RCA) based on world trade data. RCA^{US} is the same measure based on U.S. data. Appendix A describes the construction of the data.

Table 4: U.S. Bureau of Labor Statistics (BLS) Capital Shares of 3-digit Manufacturing Industries, 2002-2007 Averages

Industry	Durables	Title	NAICS	α_n	P_nY_n/PY
1	No	Petroleum and Coal Products	324	0.88	6.96 %
1	No	Chemical Products	325	0.66	14.25 %
1	No	Food, Beverage, Tobacco	311,312	0.51	10.24 %
1	Yes	Primary Metals	331	0.43	3.32 %
1	No	Paper Products	322	0.41	3.35 %
1	Yes	Transportation Equipment	336	0.40	13.53 %
2	Yes	Computer, Electronics	334	0.40	12.36 %
2	Yes	Nonmetallic Mineral Products	327	0.39	2.85 %
2	No	Plastics and Rubber Products	326	0.36	3.88 %
2	Yes	Electrical Equip., Appliances, etc.	335	0.36	2.80 %
2	Yes	Miscellaneous Manufacturing	339	0.33	3.94 %
2	Yes	Machinery	333	0.31	6.77 %
2	Yes	Fabricated Metal Products	332	0.31	7.24 %
2	No	Printing, Related Activities	323	0.24	2.62 %
2	No	Textile Mills, Textile Product Mills	313,314	0.23	1.27 %
2	Yes	Furniture and Related Products	337	0.23	1.94 %
2	Yes	Wood Products	321	0.22	1.88 %
2	No	Apparel, Leather, Applied Products	315,316	0.18	0.80 %
	Yes	***Durables***		0.36	56.17 %
	No	***Non-Durables***		0.57	43.83 %
1		***Capital Intensive***		0.56	51.64 %
2		***Labor Intensive***		0.33	48.36 %
1, 2		***Manufacturing Sector***		0.45	100.00 %

Notes: α_n denotes the capital intensity of industry / goods category n. P_nY_n/PY denotes the output share of industry / goods category n in the total output of the manufacturing sector.

$$k^1_{z,t} = \ln\left(\frac{\text{cap}}{\text{emp}}\right)_{z,t} \tag{A.2a}$$

$$k^2_{z,t} = 1 - \left(\frac{\text{pay}}{\text{vadd}}\right)_{z,t} \tag{A.2b}$$

$$k^3_{z,t} = \left(\frac{\text{invest}}{\text{pay}}\right)_{z,t} \tag{A.2c}$$

where "cap" is the total real capital stock, "emp" is total employment, "pay" is total payroll, "vadd" is total value added, and "invest" is total capital expenditure. Physical capital intensity as measured by the logarithm of the real capital stock per worker (k^1) is adopted from Antràs (2016), while capital intensity defined as 1 minus the share of total labor compensation in value added (k^2) is taken from Romalis (2004) and Jin (2012). The third measure (k^3) given as the capital to labor expenditure ratio provides an additional robustness check by using the corresponding spending flows version of equation (A.2a). Table 5 displays the correlation matrix for the three capital intensity measures. While the results indicate a relatively strong positive comovement amongst the three variants, the correlations are still sufficiently imperfect for a consideration of all three to be warranted. Turning to Table 6, we also observe that the resulting revealed comparative advantage indices positively covary across NAICS and BACI trade data samples, with correlation coefficients of moderate magnitudes.

Table 5: Correlations Across Capital Intensity Measures

	U.S. NAICS 1989-2008			**BACI World 1995-2006**		
	k1	k2	k3	k1	k2	k3
Pooled						
$k1$	1.00			1.00		
$k2$	0.56^{**}	1.00		0.54^{**}	1.00	
$k3$	0.65^{**}	0.59^{**}	1.00	0.62^{**}	0.58^{**}	1.00
Cross-Section						
$k1$	1.00			1.00		
$k2$	0.59^{**}	1.00		0.56^{**}	1.00	
$k3$	0.83^{**}	0.69^{**}	1.00	0.78^{**}	0.66^{**}	1.00

Notes: Spearman rank correlation coefficients are reported. A perfect correlation indicates that the two variables in question are perfectly monotonically related. Pooled correlations are calculated over panel data. Cross-section correlations are calculated over averaged data for the period in question. Asterisks **,* indicate significance at 1 and 5 percent levels respectively.

Lastly, we note the criteria employed for the selection of our sample of 70 countries. The criteria are adopted from

Table 6: Cross-Country RCA correlations

	U.S. NAICS 1995-2006			BACI World 1995-2006		
	$\overline{\text{RCA}}_1$	$\overline{\text{RCA}}_2$	$\overline{\text{RCA}}_3$	$\overline{\text{RCA}}_1$	$\overline{\text{RCA}}_2$	$\overline{\text{RCA}}_3$
$\overline{\text{RCA}}_1^{NAICS}$	1.00					
$\overline{\text{RCA}}_2^{NAICS}$	0.74^{**}	1.00				
$\overline{\text{RCA}}_3^{NAICS}$	0.91^{**}	0.83^{**}	1.00			
$\overline{\text{RCA}}_1^{World}$	0.62^{**}	0.31^{**}	0.59^{**}	1.00		
$\overline{\text{RCA}}_2^{World}$	0.36^{**}	0.43^{**}	0.47^{**}	0.70^{**}	1.00	
$\overline{\text{RCA}}_3^{World}$	0.50^{**}	0.31^{**}	0.58^{**}	0.86^{**}	0.75^{**}	1.00

Notes: Cross-section correlations are calculated for a sample of 76 countries using averaged data over the period 1995-2006. Spearman rank correlation coefficents are reported. A perfect correlation indicates that the two variables in question are perfectly monotonically related. Asterisks **,* indicate significance at 1 and 5 percent levels respectively.

Lane and Milesi-Ferretti (2012). First, we discard all economies with nominal GDP below $20 billion in the year 2007 as small countries can experience high or outsized current account or trade balance volatility. Second, we exclude oil-dominated countries as their external trade dynamics are highly dictated by the price of petroleum. The omission of such countries eliminates extreme outlier observations that could potentially impede any type of meaningful assessment of the relation between macroeconomic outcomes and inter-industry trade dynamics. The final list of countries used is provided in Appendix B.[10]

B Country Sample

Developed: Australia (AUS), Austria (AUT), Belgium (BEL), Canada (CAN), Denmark (DNK), Finland (FIN), France (FRA), Germany (DEU), Greece (GRC), Iceland (ISL), Ireland (IRL), Italy (ITA), Japan (JPN), Netherlands (NLD), New Zealand (NZL), Norway (NOR), Portugal (PRT), Spain (ESP), Sweden (SWE), Switzerland (CHE), United Kingdom (GBR), United States (USA).

Developing: Argentina (ARG), Bangladesh (BGD), Belarus (BLR), Brazil (BRA), Bulgaria (BGR), Cameroon (CMR), Chile (CHL), China (Mainland) (CHN), Colombia (COL), Costa Rica (CRI), Croatia (HRV), Cyprus (CYP), Czech Republic (CZE), Dominican Republic (DOM), Egypt, Arab Rep. (EGY), El Salvador (SLV), Estonia (EST), Ghana (GHA), Guatemala (GTM), Hong Kong S.A.R. (HKG), Hungary (HUN), India (IND), Indonesia (IDN), Israel (ISR), Kenya (KEN), Korea Rep. (KOR), Latvia (LVA), Lebanon (LBN), Lithuania (LTU), Malaysia (MYS), Mexico (MEX), Morocco (MAR), Pakistan (PAK), Peru (PER), Philippines (PHL), Poland (POL), Russia (RUS), Singapore (SGP), Slovak Republic (SVK), Slovenia (SVN), South Africa (ZAF), Sri Lanka (LKA), Thailand (THA), Tunisia

[10] Data availability also governs our country sample size.

(TUN), Turkey (TUR), Ukraine (UKR), Uruguay (URY), Vietnam (VNM).

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