Intersectoral Distortions, Structural Change and the Welfare Gains from Trade[*]

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Abstract

How large are the welfare gains from trade when factors are misallocated due to domestic distortions? In this paper I provide a quantitative answer to this question by incorporating distortions to the allocation of labor across broad sectors into a model of structural change and Ricardian trade. Calibrating the model using 36 years of data for a diverse set of countries I find that (1) gains from trade for net exporters of agricultural goods are overstated in models that abstract from intersectoral distortions since in those countries trade tends to exacerbate the effect of domestic frictions; (2) due to distortions developing countries have a strong unilateral incentive to protect their manufacturing sector from foreign competition and that yielding to such protectionist sentiments would negatively affect other poor countries; and (3), mitigating domestic frictions has a much larger potential payoff for poor countries when they are open to international trade.

JEL Numbers: F16, F40, O11, O19, Q17.

Keywords: gains from trade, labor distortions, structural change, trade in agriculture, nonhomothetic preferences.

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1 Introduction

How large are the welfare gains from international trade? This classic topic in the international trade literature has recently received renewed interest following the findings of Arkolakis et al. (2012). These authors show the similarity of gains from trade predicted by a range of workhorse international trade models. One feature that all those standard models have in common is that they abstract from distortions on domestic markets. Yet we have ample evidence that domestic distortions are prevalent. That domestic frictions affect the benefits of engaging in international trade has been long recognized. Using highly stylized models theoretical literature some fifty years ago showed that a country might even lose from international trade if trade exacerbates the effects of domestic distortions. The goal of this paper is to go beyond such qualitative predictions and quantify the effects of intersectoral distortions on the welfare gains from trade for a broad range of countries using a modern multi-country general equilibrium model of international trade.

The model I build uses homogeneous labor as the only primary factor of production and features three sectors: agriculture, manufacturing and services. There are four main forces affecting the sectoral composition of economic activity: (i) nonhomothetic preferences, (ii) technology, (iii) costly international trade and (iv) distortions to the allocation of labor across sectors.

To model income effects I introduce augmented CDES preferences to the applied literature. The specification of preferences I use has advantages over functional forms commonly used to model nonhomothetic tastes, such as Stone-Geary or augmented CES preferences, in that it remains nonhomothetic at all income levels. Augmented CDES preferences are more general than, and in fact nest, those two common specifications. The extra flexibility allowed by the parametrization used in this paper is important for matching data for countries with a wide range of income over long periods of time.

The trade framework used in this paper is standard. I treat agriculture and manufacturing as tradable sectors in the Ricardian fashion of Eaton and Kortum (2002) and treat services as nontradable. Since over the period of my analysis some countries have substantial current account imbalances I allow trade to be unbalanced to better capture the impact of international economic integration.

The final key component of the model is the presence of distortions to the allocation of labor across sectors. Their introduction is motivated by studies by Vollrath (2009) and Gollin et al. (2012) who document that the marginal products of labor are not equalized across sectors, suggesting labor misallocation. I do not take a stand on what the underlying sources of intersectoral distortions are and simply model the distortions as wedges between labor costs faced by producers in different sectors.

For a special case of the model with homothetic preferences, I derive an intuitive relationship between the true size of the gains from trade and the gains from trade that would be calculated using a similar model that abstracts from intersectoral distortions. The standard measure of the gains from trade needs to be adjusted by a term reflecting the trade-induced reallocation of labor across sectors. If after opening to trade labor moves towards sectors in which employment was already inefficiently high in autarky due to domestic distortions, then the true gains from trade are reduced relative to the frictionless calculation.[1] In a full model with nonhomothetic preferences the formula I derive does not hold exactly but it provides a good approximation to the magnitude of the gains from trade.

To assess the quantitative importance of intersectoral distortions for the effects of trade I calibrate the model using data on up to 44 countries over the period 1970-2005. Since the available evidence suggests that intersectoral labor distortions are especially large in poor countries I strive to include as many major developing countries as possible by combining sector-level data from a number of sources. My calibration strategy involves matching the series on sectoral employment levels, sectoral value added, sectoral bilateral trade flows and aggregate real GDP per worker. I identify the intersectoral labor distortions from the differences in value added per worker across sectors. Then I use the structure of the model to solve for productivity levels in each sector, country and year, the variables which are not directly observable in the data. Parameters necessary for this calculation are obtained through a GMM procedure that exploits the predictions of the model for sectoral labor productivity growth.

The calibrated intersectoral labor distortions imply that agricultural wages are generally depressed relative to manufacturing wages. The magnitude of the distortion tends to decrease with income, with biggest wedges in poor countries. Within non-agriculture I do not find a systematic relationship between income and the labor wedge between services and manufacturing. Overall, measured distortions within non-agriculture are also smaller than wedges between agriculture and manufacturing.

These patterns of intersectoral distortions are important for understanding the key quantitative result of this paper. I find that taking into account intersectoral labor distortions changes the magnitude of the gains from trade in an important way for a number of countries. In general, the gains from trade in my model are smaller than in standard models for countries that are net exporters of agricultural goods and larger for net exporters of manufactured goods. The intuition behind this result is simple - with domestic distortions effectively depressing wages in agriculture, production and employment in that sector would be above an efficient level in a closed economy. If trade further increases agricultural employment, which typically happens for countries that are net exporters in that sector, then trade tends to exacerbate the initial domestic distortion. Consequently, the benefits of trade for these countries are not as large as the frictionless models would predict. Quantitatively, for countries in the first quartile of the agricultural deficit to GDP ratio in 1995 the true gains from trade are on average 8.9 p.p. lower than in a standard calculation, while for the highest quartile they are 1.5 p.p. higher. In the workhorse models gains from trade depend mostly on *how much* a

[1] Throughout I assume that the labor wedges measuring underlying intersectoral distortions are not affected by the trade regime.

country trades; in a world with intersectoral distortions *what* it export matters as well.

Going beyond the issue of gains from trade, I also study the implications of intersectoral distortions for trade policy. I find that most countries would have an incentive to unilaterally impose tariffs on manufactured goods in order to pull workers out from farms. In a second-best world it might be optimal to introduce a distortion (manufacturing tariff) to partially offset the effect of another distortion (labor wedge).[2] My results illustrate that this effect can be quantitatively important for developing counties - e.g., China in 1995 could gain as much as 27% in welfare terms from from pursuing unilaterally optimal trade policy. I provide some reduced form evidence that a pro-manufacturing bias of trade policy in fact exists in developing countries. Manufacturing protectionism is a beggar-thy-neighbor policy, however, and I demonstrate that it might cause nontrivial harm to nearby poor countries.

I also look at the complementary issue of how trade openness affects the welfare cost of intersectoral distortions. Removing half of calibrated labor distortions would lead to a welfare gain of 18.3% for the the poorest quartile of countries in 1995 in the open economy, but a corresponding average gain in a hypothetical closed economy would be only 0.3%. This large difference can be explained as follows. Reducing labor wedges would increase the relative labor cost in agriculture and hence the relative price of agricultural goods. However, the calibrated preference parameters imply little substitutability in consumption across sectors so changes in relative prices would induce little adjustment in consumption. As a result, in a closed economy there would also be little change in production structure. With consumption and production almost unchanged, there is no scope for large welfare gains from lowering distortions. In contrast, when a country is open to trade an increase in the agricultural wage relative to the manufacturing wage would make its agricultural sector relatively less competitive. This would cause substitution of imports for domestic production in agriculture and associated reallocation of labor towards manufacturing. Since poor countries are found to be relatively unproductive in agriculture this reallocation results in large welfare gains.

The sectoral structure of my model and the time dimension of my data place this paper also among quantitative studies of structural change. This literature studies the forces behind the secular reallocation of labor and expenditure across agriculture, manufacturing and services in the process of economic development. In addition to two standard drivers of structural change, sector-biased productivity growth and nonhomothetic preferences, sectoral composition in my model is affected also by international trade and intersectoral distortions. This allows my model to explain more sectoral margins in the data. Trade explains why sectoral value added shares and expenditure shares might differ within a country. Intersectoral distortions account for the divergence between sectoral employment shares and value added shares that are pervasive in the data. The secondary contribution of this paper is to assess the importance of trade and changes in distortions for structural transformation over longer horizons. I find that while trade clearly matters for the sectoral

[2] However, the principle of targeting suggests that there are instruments more efficient than tariffs for correcting intersectoral labor distortions.

composition of economies in the cross section of countries at any point in time, in the long run the patterns of sectoral productivity growth and income effects are the main drivers. However, I do find evidence that reducing domestic labor distortions is associated with a faster pace of structural transformation.

Related Literature

This paper is related to a few strands of the literature. It contributes to a voluminous body of research on the welfare gains from international trade by studying the impact of domestic distortions on those gains. Attempts to quantify the benefits of trade have for a long time been the domain of Computable General Equilibrium (CGE) models, in which trade arises due to the Armington assumption that goods are differentiated by country of origin.[3] Measuring the gains due to the classic Ricardian comparative advantage channel lacked a solid theoretical foundation until the seminal contribution of Eaton and Kortum (2002). In a recent influential theoretical article, Arkolakis et al. (2012) show that in the absence of domestic distortions the gains from trade in the Armington model are the same as in the Eaton and Kortum (2002) model and similar as in the most popular implementation of the Melitz (2003) model. In this paper, I take one of those three workhorse quantitative trade models and demonstrate how the welfare gains from trade it predicts change, both analytically and quantitatively, when intersectoral allocation of labor is distorted due to domestic frictions.

The intersectoral labor distortions of this paper appear in the older theoretical trade literature as "wage differentials". Hagen (1958) demonstrates in a simple two-sector model that a country might lose from trade if the wage differential is paid by the import-competing sector. I show that an appropriately modified version of this result remains true in my multi-country general equilibrium framework. Bhagwati and Ramaswami (1963) rank various policies intended to ameliorate the effects of distortionary wage differentials in terms of their efficiency. While trade policy is never the first-best instrument, it can nevertheless increase welfare. Katz and Summers (1989) discuss the empirical relevance of intersectoral wage differentials as a motive for strategic trade policy in the context of manufacturing trade in the United States. I argue that intersectoral distortions offer a plausible rationalization for observed trade policy patterns in developing countries. Moreover, the global general equilibrium framework allows me to also quantitatively assess the impact of unilateral changes in trade policies on welfare of other countries.

In terms of modeling the production side of the economy, papers by Xu (2011) and Tombe (2012) are close predecessors to my work. Both studies combine the Eaton and Kortum (2002) trade structure with some form of friction between agriculture and nonagriculture. In the case of Xu (2011) the friction takes the form of home production in agriculture. Tombe (2012) uses a labor wedge between agriculture and nonagriculture that plays a similar role as my intersectoral

[3] See Hertel (1999) for an overview of CGE trade modeling.

distortions. There are important differences between my work and those papers, however. First, the substantive focus of the papers is different. My main interest lies in measuring the overall welfare gains from trade and in understanding how they are affected by domestic intersectoral distortions. In contrast, Tombe and Xu concentrate on explaining low levels of agricultural imports by poor countries and on quantifying the potential gains from reducing trade barriers in agriculture. Second, I introduce a flexible specification of nonhomothetic consumer preferences that nests as a special case the Stone-Geary form assumed by Tombe and Xu. The Stone-Geary specification is not sufficient to match sectoral patterns observed in my broad sample. Third, I use a completely different empirical strategy for inferring key model quantities from the observable data. In my dataset, following the gravity equation based approach of Tombe and Xu would imply time-series behavior of sectoral labor productivities that is strongly counterfactual.[4]

This paper is also related to quantitative studies taking standard theories of structural transformation to the data. Duarte and Restuccia (2010) is the closest paper in terms of broad methodology and sample coverage. Relative to that article, I add a new way of modeling nonhomothetic preferences, frictions on the domestic factor markets and interdependence among countries. Moreover, the two papers are focused on different issues. Whereas the primary interest of Duarte and Restuccia (2010) lies in assessing the importance of sectoral productivity growth for aggregate performance, I am more interested in how different forces behind structural transformation interact in determining patterns of specialization.

Although the observation that international trade might affect the path of structural transformation is not new, the literature formalizing the link is relatively scant. Matsuyama (2009) and Yi and Zhang (2010) demonstrate in simple theoretical two-country models how different rates of productivity growth across sectors might have different implications for sectoral labor shares in a closed economy and in an interdependent world. This paper uses a similar production structure as Yi and Zhang and applies it to data for multiple countries over a long period of time. The multi-country general equilibrium setting also differentiates my work from Teignier (2011), who studies how trade affects the process of structural change in a calibrated model but only for a couple of countries and under the small open economy assumption.

The rest of this paper is structured as follows. In Section 2 I present the model that forms the basis for my quantitative investigation. Section 3 describes the data and the methodology I employ to map the model to the data. In Section 4 I discuss the patterns of distortions and sectoral productivities generated by the calibrated model. The key quantitative results of the paper are presented in Section 5 which is devoted to counterfactual simulations of the model. The final Section 6 offers closing remarks.

[4] Both Xu (2011) and Tombe (2012) rely only on cross-sectional data for a single year whereas my methodology exploits the panel structure of my dataset.

2 Theoretical Framework

In this section I present the model that forms the basis for my quantitative investigation of international trade in the presence of intersectoral distortions. The model offers a rich array of determinants of sectoral labor and spending allocations across time and space. It incorporates the two standard forces in the structural change literature: (i) sector-biased productivity growth combined with low elasticity of substitution across sectors and (ii) nonhomothetic preferences with low income elasticity in agriculture and high income elasticity in services. Intersectoral labor distortions also affect the sectoral labor shares and drive a wedge between employment shares and value added shares. Finally, international trade allows for the divergence of sectoral value added shares and expenditure shares.

2.1 Economic Environment

The model world consists of N countries. Labor is the only primary factor of production in the model. This choice is driven both by data availability in the empirical implementation and by a desire to preserve the Ricardian structure of the model. There are three sectors in the economy: agriculture, manufacturing and services. Agriculture and manufacturing are tradable, while services are assumed to be nontradable. All goods are utilized in the period they are produced. I thus abstract from physical investment. Trade need not be balanced for individual countries each period but following recent approaches in quantitative trade studies I abstract from the intertemporal decisions that lead to trade deficits or surpluses. The model's solution is therefore a sequence of static equilibria.

2.2 Consumers

Individual agents have preferences defined over streams of consumption of aggregate output of agriculture C_K, manufacturing C_M and services C_S:

$$\sum_{t=0}^{\infty} \beta^t u\left(C_{At}, C_{Mt}, C_{St}\right).$$

I concentrate only on the within-period choices, essentially solving a series of static problems while taking the decisions regarding the intertemporal budgeting as given.

Intratemporal preferences are described by means of an indirect utility function

$$V\left(P_A,\, P_M,\, P_S,\, m\right) = \sum_{K\in\{A,\,M,\,S\}} \gamma_K \frac{\left(\frac{m-\sum_k P_k \bar{c}_k}{P_K}\right)^{\alpha_K} - 1}{\alpha_K}, \tag{1}$$

which gives the maximum level of utility achieved by an individual with nominal expenditure m

facing prices $\{P_K\}$.[5] This formulation of preferences augments the constant differences of elasticities of substitution (CDES) preferences by introducing subsistence consumption requirement $\bar{c}_K$.[6]

The demand system associated with (1) generalizes preference structures used in the prior literature on structural transformation. Its main advantage over the commonly used functional forms is that it gives non-vanishing roles to the two forces emphasized in the structural transformation literature and thus improves the ability of the model to match the data for a wide range of countries. One tradition attributes the pattern of falling expenditure share of agriculture and rising share of services to income effects, typically modeled by postulating Stone-Geary utility function as in Kongsamut et al. (2001). The second strand of the literature links changes in sectoral expenditure shares to changes in relative prices. That substitution effect is usually modeled with aid of CES preferences with elasticity of substitution less than one, with Ngai and Pissarides (2007) serving as a recent example. However, as discussed by Buera and Kaboski (2009) and Herrendorf et al. (2011), models relying on income or substitution channel alone fail to account for important empirical regularities of structural change. More recently, Herrendorf et al. (2009) and Buera and Kaboski (2009) worked with augmented CES preferences that nest both the Stone-Geary and homothetic CES as special cases.[7] But that specification is still quite restrictive. In particular, the allocation of marginal expenditure across sectors is independent of income level. At low income levels the income effect plays a dominant role but for high enough incomes the demand system essentially behaves like a homothetic CES. This asymmetry, for which there is no compelling theoretical justification, becomes especially problematic in empirical analysis when the sample contains observations with very different income levels, which is the case in this paper.

In contrast to other preferences used in the literature, preferences implied by (1) remain nonhomothetic regardless of income level. Denoting by $\tilde{m} = m - \sum_K P_K \bar{c}_K$ the discretionary expenditure to simplify notation, the Marshallian demand for sector K goods is given by:

$$C_K = \bar{c}_K + \frac{\gamma_K \left(\frac{\tilde{m}}{P_K}\right)^{\alpha_K + 1}}{\sum_k \gamma_k \left(\frac{\tilde{m}}{P_k}\right)^{\alpha_k}}. \tag{2}$$

The ratio of expenditures on sectors K and L is asymptotically (for high incomes) given by

$$\frac{\gamma_K \left(\frac{m}{P_K}\right)^{\alpha_K}}{\gamma_L \left(\frac{m}{P_L}\right)^{\alpha_L}},$$

which depends on the level of expenditure as long as $\alpha_K \neq \alpha_L$ and depends on relative prices

[5] There is no closed-form solution for direct utility function $u\left(C_A\, C_M,\, C_S\right)$ corresponding to (1) except in some special cases.

[6] The specific form of CDES preferences obtained with $\bar{c}_K = 0$ is from Jensen et al. (2011). Those authors extend the applicability to cases of interest for this paper of the indirect addilog preferences, which date back to Houthakker (1960) and beyond.

[7] Utility function in those papers takes the form $U = \left(\sum_K \gamma_K^{-\frac{\varepsilon-1}{\varepsilon}} \left(C_K - \bar{c}_K\right)^{\frac{\varepsilon-1}{\varepsilon}}\right)^{\frac{\varepsilon}{\varepsilon-1}}$.

unless $\alpha_K = \alpha_L = 0$. The augmented CDES demand in fact nests all the systems mentioned in the preceding paragraphs. With $\alpha_K \equiv \varepsilon - 1$ and $\bar{c}_K \equiv 0$ constant across sectors we obtain the standard homothetic CES preferences with elasticity of substitution ε. Taking the limit $\alpha_K \to 0$ in (1) while allowing $\bar{c}_K \neq 0$ we can recover Stone-Geary preferences. Combining $\alpha_K \equiv \varepsilon - 1$ and arbitrary $\bar{c}_K$ yields the demand system consistent with augmented CES. An additional advantage of the CDES demand system over CES is that CDES gives a richer pattern of substitution among goods while still remaining parsimoniously parametrized.[8]

While "pure" CDES preferences (with $\bar{c}_K \equiv 0$) already incorporate one form of nonhomotheticity, I also adhere to the long tradition and assume that consumption of agricultural goods must exceed some subsistence level $\bar{c}_A > 0$. This extra parameter increases the ability of the model to match expenditure patterns at low income levels. Throughout the paper I set $\bar{c}_M = \bar{c}_S = 0$.

There are L_i identical agents in country i and each of them supplies one unit of labor inelastically. For simplicity I assume that all agents within a country receive the same income.[9]

2.3 Production

In each sector there is a unit measure of intermediate goods indexed by $h \in [0, 1]$. Intermediates in any sector are produced using constant returns to scale technology combining labor and the aggregate output of that sector. Specifically, the production function for variety h in sector K in country i at time t is:

$$q_{Kit}(h) = \kappa_K z_{Kit}(h) \, L_{Kit}(h)^{\beta_K} \, Q_{Kit}(h)^{1-\beta_K},$$

where $z_{Kit}(h)$ denotes the variety-sector-country-year-specific productivity.[10] In what follows, I omit time subscripts unless needed for clarity. Labor shares $0 < \beta_K \leq 1$ are sector-specific but are constant across countries and time.[11]

The nontraded aggregate output of industry K is costlessly assembled from all intermediates of that industry using the CES technology

[8]For example, CDES allows pairs of goods to be Allen-complements which is impossible with CES. In that sense CDES is also more flexible than the constant ratios of elasticities of substitution (CRES) family, which was recently used to model nonhomothetic preferences in the trade literature by Caron et al. (2012) and Fieler (2011). In the context of this paper, CDES is also easier to implement numerically than CRES since the latter does not give a closed form solution for direct demand functions.

[9]For example, if take-home wages differ between sectors agents can pool incomes in their extended families whose sectoral employment is representative of the entire economy. The equal-expenditure assumption simplifies the quantitative analysis by allowing me to avoid tracking the within-country distribution of expenditures. Such need would arise with unequal incomes since preferences represented by (1) do not allow for income aggregation across consumers (indirect utility (1) is not of the Gorman polar form).

[10]The constant $\kappa_K = \beta_K^{\beta_K} (1 - \beta_K)^{(1-\beta_K)}$ is introduced to simplify notation.

[11]For data availability reasons I do not pursue richer input-out structures, such as in the model of Caliendo and Parro (2011).

$$Q_{Ki} = \left[\int_0^1 x_{Ki}(h)^{\frac{\sigma-1}{\sigma}} \, dh \right]^{\frac{1}{\sigma-1}},$$

where σ is the elasticity of substitution across varieties and $x_{Ki}(h)$ is the quantity of variety h used in production in sector K in country i. The aggregate sectoral output is used both as an input for production of intermediates and to satisfy final demand.

The product market is perfectly competitive. Given prices of intermediates $p_{Ki}(h)$ prevailing in market i, the price index for the aggregate output is given by $P_{Ki} = \left[\int_0^1 p_{Ki}(h)^{1-\sigma} \, dh \right]^{\frac{1}{1-\sigma}}$. The cost of producing a unit of variety h in sector K and country i is then $c_{Ki}/z_{Ki}(h)$, where

$$c_{Ki} = w_{Ki}^{\beta_K} P_{Ki}^{1-\beta_K} \tag{3}$$

is the cost of the input-bundle used by sector K and where w_{Ki} is the wage in sector K in country i.

2.4 Distortions

The fact that the wage w_{Ki} appearing in (3) is sector-specific is a central feature of the model. Since labor is assumed to be homogeneous, differential wages in the model do not reflect heterogeneity in productivity. Instead, wage differentials are meant to capture distortions to the intersectoral allocation of labor in a tractable way. There are at least two interpretations of these distortions that have equivalent implications in the model.

First, workers in different sectors might be paid different wages. The failure of wage equalization might reflect, for example, differences in unionization levels across sectors or wage regulations that differ by sector. In this case distortionary institutions and policies effectively restrict worker entry to some sectors and thus limit the ability of labor mobility to equalize take-home wages.

An alternative explanation for sector-specific wages is a presence of sector-specific labor taxes or subsidies. The wage w_{Ki} affecting the production costs summarizes the labor cost to the producer. The model is thus consistent with an interpretation in which perfect labor mobility equalizes the take-home wage w_i for workers in all sectors and differences in labor costs arise solely due to differences in labor taxes t_{Ki}, with $w_{Ki} = (1 + t_{Ki}) w_i$. As long as the net revenue from labor taxes and subsidies is redistributed lump-sum to workers, the equilibrium with labor taxes looks the same as an equilibrium in which distortions drive a wedge of the same magnitude between sectoral take-home wages.[12]

What matters for the allocation of labor across sectors is the relative magnitude of distortions

[12] It is also possible that wage differentials across sectors might reflect real mobility costs rather than distortions. While the model can in principle accommodate this possibility as well, welfare calculations in counterfactual exercises would require me to take a stand on the structure of such mobility costs. Modeling switching costs is beyond the scope of this paper so I attribute wage differentials to distortions only.

across sectors and not their absolute level. Distortions will be therefore summarized by the wedge between wage in agriculture or services and manufacturing wage, i.e. I will call the objects

$$\xi_{Ai} \equiv \frac{w_{Ai}}{w_{Mi}}, \quad \xi_{Si} \equiv \frac{w_{Si}}{w_{Mi}} \tag{4}$$

the wedge in agriculture and the wedge in services, respectively. By construction the wedge in manufacturing is then equal to one, $\xi_{Mi} \equiv 1$.

The key feature of all distortions described above is that they cause wages faced by firms to differ across sectors. In general, there could be other distortions in the economy that do not affect wages directly. Some of such distortions would have the same general equilibrium implications as appropriately chosen labor wedges.[13] Thus in principle, labor wedges in the model could be used to summarize a broad range of distortions in factor and output markets. However, as discussed further in Section 3.2, in taking the model to the data I can identify only distortions that directly affect the relative labor costs across sectors. For this reason, I occasionally refer to labor wedges as labor distortions in this paper.

2.5 International Trade

Intermediate goods in agriculture and manufacturing are tradable subject to the standard iceberg transportation costs. Delivering a unit of variety h in sector K from country i to country j requires shipping $\tau_{Kji} \geq 1$ units of the good, with $\tau_{Kjj} = 1$. With perfect competition, the price of variety h delivered to j from i is

$$p_{Kji}(h) = \frac{c_{Ki}\tau_{Kji}}{z_{Ki}(h)}.$$

Every country will choose the cheapest source for each variety. The price actually paid in country j for a variety h in a tradable sector K is therefore

$$p_{Kj}(h) = \min_{i=1,..,N} \{p_{Kji}(h)\}.$$

In tradable sectors, country i draws productivity $z_{Kit}(h)$ in variety h from a distribution with cumulative distribution function F_{Kit}, with draws independent across countries, sectors, varieties and time. Following Eaton and Kortum (2002)), the realizations are assumed to come from the Frechet distribution with $F_{Kit}(z) = e^{-T_{Kit}z^{-\theta_K}}$. The parameter T_{Kit} is related to country i's average efficiency in sector K. The parameter θ_K is an inverse measure of the dispersion of productivity draws and is assumed to be constant across countries and time.

Let X_{Kj} denote the total expenditure on sector K in country j and X_{Kji} the expenditure on subset of the goods sourced from country i. Then the Eaton and Kortum (2002) structure delivers

[13] For example, a mixture of sector-specific labor tax and output tax coupled with equivalent subsidy for intermediates would have the same macroeconomic implications as an appropriately chosen labor wedge.

the following expressions for the share of expenditure in country j going to goods from country i:

$$\pi_{Kji} = \frac{X_{Kji}}{X_{Kj}} = \frac{T_{Ki}\left(c_{Ki}\tau_{Kji}\right)^{-\theta_K}}{\sum_m T_{Km}\left(c_{Km}\tau_{Kjm}\right)^{-\theta_K}}.$$

The price index in the tradable sectors can be written as[14]

$$P_{Kj} = \Gamma_K \left[\sum_i T_{Ki}\left(c_{Ki}\tau_{Kji}\right)^{-\theta_K}\right]^{-\frac{1}{\theta_K}}, \ K \in \{A, M\}.$$

Substituting the expression for the cost of the input bundle from (3), trade shares and the price indices can be expressed as:

$$\pi_{Kji} = \frac{T_{Ki}\left(w_{Ki}^{\beta_K} P_{Ki}^{1-\beta_K}\tau_{Kji}\right)^{-\theta_K}}{\sum_m T_{Km}\left(w_{Km}^{\beta_K} P_{Km}^{1-\beta_K}\tau_{Kjm}\right)^{-\theta_K}}. \tag{5}$$

$$P_{Kj} = \Gamma_K \left[\sum_i T_{Ki}\left(w_{Ki}^{\beta_K} P_{Ki}^{1-\beta_K}\tau_{Kji}\right)^{-\theta_K}\right]^{-\frac{1}{\theta_K}}, \ K \in \{A, M\}. \tag{6}$$

In the nontraded service sector dispersion of productivity draws would play no interesting role. I therefore assume that all services within a country j are produced with the same efficiency $z_{Sj}(h) = B_{Sj}$. The price level for services then simply collapses to:

$$P_{Sj} = \frac{w_{Sj}}{B_{Sj}^{1/\beta_S}}, \tag{7}$$

where the presence of the β_S parameter reflects intermediate input use.

2.6 Equilibrium

In this subsection I give conditions describing the equilibrium of the model world economy. Towards that goal, I first need to introduce some accounting notation. Let L_{Ki} denote employment in sector K in country i and let Y_i denote the GDP of country i, equal to its labor income:

$$Y_i = w_{Ai}L_{Ai} + w_{Mi}L_{Mi} + w_{Si}L_{Si}.$$

Let D_i be country i's overall trade deficit, where we require that deficits sum to zero at the world level:

$$\sum_j D_j = 0. \tag{8}$$

[14] $\Gamma_K \equiv \Gamma\left(\frac{\theta_K+1-\sigma}{\theta_K}\right)$, where $\Gamma(\cdot)$ is a Gamma function.

The budget constraint of agents in country i then dictates that total final demand by consumers in i is given by $X_i^F = Y_i + D_i$. To simplify notation in what follows I denote by $\tilde{X}_i^F$ the final demand spending net of subsistence expenditure in country i: $\tilde{X}_i^F = X_i^F - L_i \sum_K P_{Ki}\bar{c}_K$. Then using the solution to the consumer's problem in (2), we can write the final demand in sector K by consumers from i as

$$L_i P_{Ki}\left[\bar{c}_K + \frac{\gamma_K\left(\frac{\tilde{X}_i^F/L_i}{P_K}\right)^{\alpha_K+1}}{\sum_k \gamma_k\left(\frac{\tilde{X}_i^F/L_i}{P_k}\right)^{\alpha_k}}\right].$$

On the production side, let Z_{Ki} be the value of gross output of sector K in country i. The production technology implies that demand from intermediate goods producers in sector K for that sector's output is a fraction $(1-\beta_K)$ of the value of gross output, i.e. $(1-\beta_K)\,Z_{Ki}$. Total spending (absorption) X_{Ki} on sector K consists of the final demand by consumers and of demand by intermediate inputs producers

$$X_{Ki} = (1-\beta_K)\,Z_{Ki} + L_i P_{Ki}\left[\bar{c}_K + \frac{\gamma_K\left(\frac{\tilde{X}_i^F/L_i}{P_K}\right)^{\alpha_K+1}}{\sum_k \gamma_k\left(\frac{\tilde{X}_i^F/L_i}{P_k}\right)^{\alpha_k}}\right].$$

We can now write the market clearing conditions in the tradable sectors as follows. The value of gross output of sector K in country i must be equal to the value of imports by all countries (including i) of goods from i in that sector:

$$Z_{Ki} = \sum_j \pi_{Kji}X_{Kj} = \sum_j \pi_{Kji}\left\{(1-\beta_K)\,Z_{Kj} + L_j P_{Kj}\left[\bar{c}_K + \frac{\gamma_K\left(\frac{\tilde{X}_j^F/L_j}{P_K}\right)^{\alpha_K+1}}{\sum_k \gamma_k\left(\frac{\tilde{X}_j^F/L_j}{P_k}\right)^{\alpha_k}}\right]\right\},$$

where I have used the fact that $X_{Kji} = \pi_{Kji}X_{Kj}$, with π_{Kji} defined in (5). Finally, using the fact that value added $w_{Ki}L_{Ki}$ constitutes a fraction β_K of gross output, we can write the market clearing conditions as follows: for all $i = 1, ..., N$

$$w_{Ki}L_{Ki} = \sum_j \pi_{Kji}\left\{(1-\beta_K)\,w_{Kj}L_{Kj} + \beta_K L_j P_{Kj}\left[\bar{c}_K + \frac{\gamma_K\left(\frac{\tilde{X}_j^F/L_j}{P_K}\right)^{\alpha_K+1}}{\sum_k \gamma_k\left(\frac{\tilde{X}_j^F/L_j}{P_k}\right)^{\alpha_k}}\right]\right\}, \quad K \in \{A,\, M\}. \tag{9}$$

Since services are nontradable, the market clearing condition in that sector takes a simpler form:

$$w_{Si}L_{Si} = L_i P_{Si}\left[\bar{c}_S + \frac{\gamma_S\left(\frac{\tilde{X}_i^F/L_i}{P_S}\right)^{\alpha_S+1}}{\sum_k \gamma_k\left(\frac{\tilde{X}_i^F/L_i}{P_k}\right)^{\alpha_k}}\right], \quad i = 1, ..., N. \tag{10}$$

Finally, the labor market clearing condition requires that

$$L_{Ai} + L_{Mi} + L_{Si} = L_i, \quad i = 1, ..., N. \tag{11}$$

To summarize the characterization of the world equilibrium in the presence of distortions, I present its formal definition.

Definition 1. Given labor wedges $\{\xi_{Ai}, \xi_{Si}\}_{i=1}^{N}$, technology parameters $\{T_{Ai}, T_{Mi}, B_{Si}\}_{i=1}^{N}$, labor endowments $\{L_i\}_{i=1}^{N}$, trade costs $\{\tau_{Aji}, \tau_{Mji}\}_{i=1,..,2;\, j=1,...,N}$ and trade deficits $\{D_i\}_{i=1}^{N}$ satisfying (8), the world equilibrium can be summarized as a collection of manufacturing wages $\{w_{Mi}\}_{i=1}^{N}$ and labor allocations $\{L_{Ai}, L_{Mi}, L_{Si}\}_{i=1}^{N}$ such that (i) goods markets (9)-(10) clear and (ii) the labor market clearing condition (11) is satisfied.

Starting from manufacturing wages and labor allocation, the rest of the equilibrium quantities can be determined as follows. Given w_{Mi} and wedges, the remaining wages are trivially given by (4). Given wages, prices can be found from the system of equations (6)-(7). Given wages and prices and trade costs, trade shares can be computed using (5). Given labor allocation, wages, prices and deficits we easily find final expenditures $\tilde{X}_i^F = \sum_K w_{Ki} L_{Ki} + D_i - \sum_K \bar{c}_{Ki} P_{Ki}$. By construction, all these quantities are consistent with optimization by firms and households.

2.7 Calculating the Welfare Gains from Trade

The key question this paper aims to answer is how intersectoral distortions affect the welfare gains from trade. The full model does not offer a closed form expression for the gains from trade. However, a special case of the model with homothetic preferences presented in this section clearly illustrates the main mechanism through which domestic distortions modify the magnitude of the gains from trade. For that special case I derive a formula for the gains from trade that also provides a good approximation for welfare gains in the full model with augmented CDES preferences, as I show numerically below.

Formally, with homothetic preferences I define the welfare gains from trade for county j as

$$GFT_j \equiv 1 - \frac{V_j^A}{V_j^T},$$

where V_j^T and V_j^A denote the welfare in county j in the trade and autarky equilibrium, respectively. Welfare here is measured as the level of utility of a representative worker given the representation of preferences in terms of a utility function that is homogeneous of degree one. The following proposition isolates the impact of distortions on gains from trade in this setting.

Proposition 1. *Suppose that consumer preferences are given by a CES utility function and suppose that trade is balanced in each country. Consider two models consistent with the observed sectoral expenditure shares e_{Kj}^T and trade intensities π_{Kjj} for country j: one with intersectoral distortions* *summarized by wedges $\{\xi_{Kj}\}$ and one without domestic frictions. Then the relationship between the welfare gains from trade GFT_j calculated in the model with intersectoral distortions, and gains from trade GFT_j^{ND} calculated in a model without distortions, is given by*

$$GFT_j = 1 - \underbrace{\frac{\left(\sum_K \xi_{Kj} L_{Kj}^A\right)}{\left(\sum_K \xi_{Kj} L_{Kj}^T\right)}}_{\Upsilon_j} \left(1 - GFT_j^{ND}\right), \tag{12}$$

where L_{Kj}^T denotes sector K employment in the baseline trade equilibrium and L_{Kj}^A denotes the corresponding employment in the hypothetical autarky in the distorted model.

Proof. See Appendix C.1. □

Expression (12) has an intuitive interpretation. Gains from trade in a model with intersectoral distortions can be decomposed into a term reflecting gains from trade in the absence of distortions and the term Υ_j representing the labor reallocation channel. Without distortions, $\xi_{Kj} = 1$ in all sectors and hence $\Upsilon_j = 1$. When $\Upsilon_j > 1$, $GFT_j < GFT_j^{ND}$ so the standard model overstates the magnitude of the gains from trade. But $\Upsilon_j > 1$ if on net employment in sectors with relatively low wages faced by producers (low ξ_K) is higher in the trade equilibrium than in autarky. In autarky, relatively low wages faced by producers in sector K would lead to expansion of that sector beyond what would be socially optimal. $\Upsilon_j > 1$ means that opening to trade leads to even further expansion of employment in low wage sectors. Thus if trade tends to exacerbate the effect of domestic distortions then gains from trade are lower than what a frictionless framework would predict. Symmetrically, if $\Upsilon_j < 1$ then trade tends to mitigate the effects of domestic intersectoral distortions so the gains from trade are higher than predicted by standard models.

For CES preferences the gains from trade can be calculated more explicitly as

$$GFT_j = 1 - \Upsilon_j \left[\sum_K e_{Kj}^T \left(\pi_{Kjj}^{-\frac{1}{\theta_K}\frac{1}{\beta_K}}\right)^{1-\varepsilon}\right]^{-\frac{1}{1-\varepsilon}}. \tag{13}$$

Gains from trade in this case can be naturally decomposed into the labor reallocaion channel Υ_j and traditional gains from trade within sector K, $\pi_{Kjj}^{-\frac{1}{\theta_K}\frac{1}{\beta_K}}$, weighted by sector K's expenditure share e_{Kj}^T.

If we lived in a world with balanced trade, no distortions and preferences for broad sectoral outputs reasonably approximated by the CES specification, then GFT_j could be calculated easily with minimal requirements for data. All that would be needed is sectoral expenditure shares e_{Kj}^T, trade intensities π_{Kjj}, as well as a few parameters: elasticity of substitution ε, sectoral shares of VA in gross output β_K and productivity dispersion parameters θ_K. All these quantities can be computed from the data or estimated under fairly weak assumptions. Introducing intersectoral distortions by itself does not substantially complicate the calculation. Given wedges $\{\xi_{Kj}\}$, GFT_j can still be calculated in closed form using only information from the observed trade equilibrium. The only additional data required is on sectoral trade deficits.[15]

However, since in reality trade is not balanced it would not be appropriate to use actual trade intensities in the calculation of gains from trade. The effect of aggregate trade deficits needs to be purged first. Furthermore, some aspects of the data cannot be explained well by a model with homothetic preferences when the sample contains countries of widely different income levels. For these reasons, I need to calibrate the full model.

3 Data and Calibration

In this section I describe how the theoretical model is mapped to the data. The goal of the calibration exercise is to put numbers to all objects whose magnitude I need to know in order to perform model-based counterfactual calculations. The most important objects can be classified into three groups: measures of intersectoral distortions ξ_K, measures of sectoral productivity levels, prices and wages, and parameters of consumer preferences.

I identify distortions from the data using the model's simple relationship between wedges, VA and employment. As a second step, I take certain observable variables, treat them as equilibrium outcomes and use the general equilibrium structure of the model to back out quantities of interest for which I can not get data directly. Results of this step depend on the assumed value of preference parameters. Finally, I use the time-series predictions of the model from the second step for sectoral labor productivity growth to discipline preference parameters.

The particular choice of calibration approach I follow is partially determined by what variables I can observe in the data. I thus start with a brief description of the data. More exhaustive details on construction of variables and data sources are presented in the Data Appendix.

3.1 Data Overview

Structural change is a long-term process so it is best studied using long time series that can capture the secular trends in the data. The availability of such long series is rather limited at the sector level, however. The time series with sectoral data are particularly scarce for developing countries. Those countries are especially interesting for the purpose of this paper, however, since precisely in those countries we expect the impact of the intersectoral distortions to be large.

To maximize the breadth and time span of the sample while maintaining acceptable quality of the data I combine sectoral data from four sources: EU KLEMS project, GGDC 10-sector database, OECD STAN database and Asian Productivity Organization database. The result is an

[15] See formula (35) in Appendix C.1 for an expression for Υ_j in terms of data observed in the baseline equilibrium. Even with distortions, numerical simulation is not required to calculate GFT_j when trade is balanced and preferences are of the CES form.

unbalanced panel of between 26 and 44 countries over the period 1970-2005. I aggregate the data to three sectors, which I call agriculture, manufacturing and services. These sources provide consistent and comparable series for total employment, gross value added in current prices and value added price deflators. Since the focus of this paper is on the long run rather than business cycle-frequency movements, all data is smoothed using the Hodrick-Prescott filter with smoothing parameter 25 before it is fed into the calibration.[16]

International trade data comes from two sources. For bilateral trade flows between 1970-2000 I use the NBER-UN dataset compiled by Feenstra et al. (2005). Trade flows for 1995-2005 are taken from the BACI database prepared by researchers at CEPII (Gaulier and Zignago (2010)). In the overlapping years 1995-2000 I take a weighted average of bilateral trade flows from both sources (which are very highly correlated). To map the trade data at the 4-digit SITC level into two tradable sectors, agriculture and manufacturing, I start with the SITC to ISIC concordance from WITS and subject it to some minor adjustments.

Bilateral trade shares are computed as follows:

$$\pi_{Kji} = \frac{X_{Kji}}{VA_{Kj}\beta_K^{-1} + IMP_{Kj} - EXP_{Kj}}, \tag{14}$$

where X_{Kji} is the U.S. \$ value of imports of goods in sector K by country j from i, VA_{Kj} is value added in industry K in j expressed in U.S. dollars, IMP_{Kj} and EXP_{Kj} are total imports and exports, respectively, to all other countries that are in the sample in the year of the calculation. The denominator in (14) represents the total absorption in j in sector K. Since I have consistent data on VA while the trade data is at the gross output level, I calculate the value of gross production by dividing the VA by the share of VA in gross output β_K. I calculate those shares as the median share of VA in gross output for the subsample of countries for which I have the required data (EU KLEMS subsample) and find $\beta_A = 0.50$, $\beta_M = 0.33$, $\beta_S = 0.57$. Imports from home are computed as $X_{Kjj} = VA_{Kj}\beta_K^{-1} - EXP_{Kj}$ which ensures that the import shares sum to one for each country. Trade flows and VA series are also used to compute the overall trade deficit of a country relative to its nominal GDP through the formula:[17]

$$\delta_{it} = \frac{IMP_{Ait} - EXP_{Ait} + IMP_{Mit} - EXP_{Mit}}{VA_{Ai} + VA_{Mi} + VA_{Si}}. \tag{15}$$

Finally, aggregate data (such as GDP at constant international prices and the level of exchange rates) is taken from version 7.0 of the Penn World Table (Heston et al. (2011)).

[16] The value of the smoothing parameter I use falls in the 6.25-100 range standard in the literature for annual data. This particular choice is not crucial for the results of the paper.

[17] In accordance with the model this formula treats services as nontradable. Data on international trade in services for a broad range of countries is very limited but the situation is likely to improve in the future as attempts to measure bilateral flow of services are on the rise. For the period under consideration in this paper trade in service represents about 20% of world trade.

3.2 Identifying Wedges

In the model labor is the only factor of production. Consequently, payments to labor in a sector are equal to sectoral value added and hence VA per worker measures the sectoral wage. The labor wedge in the model is thus equal to relative value added per worker. In taking the model to the data I keep this simple mapping from VA and employment to wedges by calculating the wedge in sector $K \in \{A, S\}$ as

$$\xi_{Ki} = \frac{VA_{Ki}/L_{Ki}}{VA_{Mi}/L_{Mi}}, \tag{16}$$

where VA_{Ki} is the measured sectoral VA and L_{Ki} is measured sectoral employment level. I therefore take the differences in VA per worker in the data as an evidence for the intersectoral distortions to the allocation of labor.

Labor wedges in this paper are meant to measure differences in value marginal product of labor ($VMPL$) across sectors. I know clarify two issues. First, I explain why differences in $VMPL$ across sectors provide a conceptually robust measure of labor distortions. Second, I discuss whether wedge calculated as in (16) provides a quantitatively good measure of relative $VMPL$.

In the model the wage faced by producers in sector K equals $VMPL_K$, so intersectoral wage differences imply that $VMPL$ is not equalized across sectors. Failure to equalize $VMPL$ would imply the presence of labor distortions also in richer models. For example, in a model with capital $VMPL$ would be equalized across sectors in the absence of distortions affecting relative labor costs, regardless of whether capital allocation is itself distorted or not.[18] The flip side of this argument is that (16) can only identify distortions that directly affect relative labor costs. With the available data I can not identify distortions that might affect the economic efficiency through other channels.

A separate issue is how well the relative VA per worker (16) measures the relative $VMPL$ between sectors. There are reasons other than labor distortions that could explain why VA shares and labor shares might diverge. A natural alternative explanation is differences in factor intensity across sectors. In Appendix D I show that in a model with common Cobb-Douglas technology in capital and labor across countries the labor wedge would simply be proportional to the wedge as measured in (16), with the factor of proportionality given by the relative factor shares. However, at the level of aggregation used in this paper factor intensity differences are likely not very large. In Appendix D I also show that in a subsample of countries for which data from a recent WIOD database is available wedges based on VA per worker are on average very similar and highly correlated to wedges based on labor compensation per hour worked, which should control for differences in factor intensity and hours worked across sectors. Moreover, under the standard assumption that factor shares are common across countries and stable over time, differences in factor intensity across sectors alone can not explain the cross sectional and time-series variation in wedges (16).

It might also be the case that differences in value added per worker reflect differences in levels of

[18] See Appendix D.

human capital per worker across sectors, an issue abstracted from by my model with homogeneous labor. In Appendix D I calculate wedges based on labor compensation per hour worked within three skill groups for the subsample of countries with WIOD data. Only 15% of the size of average implied labor distortion between agriculture and manufacturing is eliminated once we control for skill levels in this crude fashion.

By attributing the differences in VA per worker entirely to distortions to labor allocation in this study I likely somewhat overstate the magnitude of distortions. But differences in value marginal product of labor across sectors appear to be a robust feature of the data not specific to my simple way of measuring wedges. In more detailed cross-sectional studies Vollrath (2009) and Gollin et al. (2012) document the prevalence of such implied inefficiencies in developing countries. The latter paper, in particular, concludes that large productivity gaps between agriculture and nonagriculture (wedges in my terminology) remain in their dataset after they take into account a number of measurement issues.[19] Finally, the methodology I develop below can be implemented for alternative values of wedges. While presenting the findings of key counterfactuals I thus discuss their sensitivity to alternative assumptions about the magnitude of distortions.

3.3 Calculating Sectoral Productivity Levels

Having already determined the wedges, I now solve for sectoral labor productivity levels using the market clearing conditions of the model and observed data on employment, value added, trade flows and aggregate productivity. Aggregate productivity in the model is measured in the same way as in the Penn World Tables using Geary-Khamis international prices. The discussion for now will assume that the preference parameters $\{\alpha_K, \gamma_K, \bar{c}_K\}$ have been fixed. Calibration of those parameters will be discussed in Section 3.4.

What exactly is understood by labor productivity needs some explanation. In the model, the production functions were specified for gross output, not value added. So, first, we can define the "multi-factor" productivity as

$$B_{Ki} \equiv \Gamma_K^{-1} T_{Ki}^{1/\theta_K} \pi_{Kii}^{-1/\theta_K}, \tag{17}$$

where π_{Kii} is the share of expenditure on sector K that goes to the domestic producers in country i. In a closed economy $\pi_{Kii} = 1$ and B_{Ki} would simply be the average efficiency $z_{Ki}(h)$ across the intermediate goods producers. In tradable sectors of an open economy MFP also captures the selection effect, in that varieties in which country i is not productive enough are not produced domestically but are imported instead.[20] Holding the state of technology in country i fixed, an increased penetration by imports would lead to higher measured multi-factor productivity. Using

[19] Controlling for hours work and quality of human capital in their dataset lowers the average size of the wedge by 40%. Their starting point has data of lower quality than I use in this paper, however.

[20] Finicelli et al. (2009) show that (17) is the appropriate measure of MFP in the Eaton and Kortum (2002) model.

the general equilibrium structure of the model it can be then shown that

$$B_{Ki} = \left(\frac{w_{Ki}}{P_{Ki}}\right)^{\beta_K}.$$

Having defined the multi-factor productivity, we can use the fact that value added is a constant share β_K of gross output in industry K and define labor productivity as

$$A_{Ki} \equiv B_{Ki}^{1/\beta_K} = \frac{w_{Ki}}{P_{Ki}}. \tag{18}$$

Observe that conditional on wages there is a one-to-one mapping between sectoral price levels and sectoral labor productivities in the model. Hence "solving for labor productivities" and "solving for price levels" are used interchangeably.

Key to the calibration are the market clearing conditions (9)-(10). The basic idea is to treat them as a function of observed quantities and use them to solve for sectoral prices and wages. To pin down wages and productivity levels across countries, the model matches the following quantities by design:

i) Sectoral employment levels L_{Ki}

ii) Sectoral nominal value added VA_{Ki}

iii) Trade flows in agriculture and manufacturing X_{Aji}, X_{Mji}

iv) Aggregate productivity (real GDP per worker) y_i.

The data on sectoral employment, VA and trade flows is sufficient to calculate wage levels in the model. To calibrate sectoral productivity levels, I need some extra information and this is where the data on aggregate productivity becomes useful. To see why it is the case, let E_{Kj} denote per worker final consumption expenditure on aggregate output of sector K. The market clearing conditions (9)-(10) and the corresponding budget constraint of agents in country i can then be written conveniently as

$$\begin{aligned}
w_{Mi}\xi_{Ai}L_{Ai} &= \sum_j \pi_{Aji}\left\{(1-\beta_A)\, w_{Mj}\xi_{Aj}L_{Aj} + \beta_A L_j E_{Aj}\right\} \\
w_{Mi}L_{Mi} &= \sum_j \pi_{Mji}\left\{(1-\beta_M)\, w_{Mj}L_{Mj} + \beta_M L_j E_{Mj}\right\} \\
w_{Mi}\xi_{Si}L_{Si} &= (1-\beta_S)\, w_{Mi}\xi_{Si}L_{Mj} + \beta_S L_i E_{Si} \\
\sum_K E_{Ki} &= w_{Mi}\left(\xi_{Ai}L_{Ai} + L_{Mi} + \xi_{Si}L_{Si}\right)(1+\delta_i)/L_i.
\end{aligned} \tag{19}$$

With wedges $\{\xi_{Ai}, \xi_{Si}\}$ given by (16), trade shares $\{\pi_{Aji}, \pi_{Mji}\}$ computed as in (14) and deficits as a share of GDP $\{\delta_i\}$ computed as in (15), it can be verified by direct substitution that the solution for manufacturing wages and expenditures solving the above system of equations in terms of observable quantities (i) - (iii) is given by:[21]

$$\begin{aligned} w_{Mi} &= VA_{Mi}/L_{Mi} \\ E_{Ki} &= \left(VA_{Ki} + \sum_j X_{Kij} - \sum_j X_{Kji} \right) /L_i. \end{aligned} \tag{20}$$

Now we need to find three sectoral price levels $\left\{P_{Aj},\, P_{M_j},\, P_{Sj}\right\}$ for each country j. To pin down those $3N$ prices, I use $3N$ restrictions that prices must satisfy. First, sectoral prices must be such that given those prices consumers optimally choose sectoral expenditures calculated in (20). Formally, sectoral prices $\left\{P_{Aj},\, P_{M_j},\, P_{Sj}\right\}$ must be consistent with sectoral expenditure share equations:

$$\frac{E_{Kj}}{\sum_k E_{kj}} = \frac{1}{\sum_k E_{kj}} \left[P_K \bar{c}_K + \left(\sum_k E_{kj} - P_{Aj}\bar{c}_A \right) \frac{\gamma_K \left(\frac{\sum_k E_{kj} - P_{Aj}\bar{c}_A}{P_K} \right)^{\alpha_K}}{\sum_k \gamma_k \left(\frac{\sum_k E_{kj} - P_{Aj}\bar{c}_A}{P_k} \right)^{\alpha_k}} \right]. \tag{21}$$

Since expenditure shares sum to one this restriction gives two independent equations for each country. To find three prices of sectoral output for each country we therefore need an additional set of restrictions. I use data on aggregate productivity - target (iv) above - as a source of those additional restrictions.

The empirical measure of aggregate labor productivity I use is real GDP per worker y_i. It is constructed as PPP-adjusted GDP from PWT 7.0 divided by total employment L_i. To be consistent with that empirical metric, I calculate the corresponding real GDP in the model using methodology that is analogous to one applied in the development of the PWT. In order to do that, I first choose a reference year - 1995 - in which to compute the Geary-Khamis international prices for aggregate sectoral outputs that are used to compare real GDP across countries and over time. Given nominal VA ($w_{Ki}L_{Ki}$) and the price index (P_{Ki}) we can calculate the real value added in sector K in country i as $q_{Ki} = w_{Ki}L_{Ki}/P_{Ki}$. The Geary-Khamis price of good K is then

$$p_K = \sum_{i=1}^{N} \frac{q_{Kit_R}}{\sum_{j=1}^{N} q_{Kjt_R}} \frac{P_{Kit_R}}{p_{it_R}}, \tag{22}$$

where p_{it_R} is the PPP price level in country i in the reference year defined as

$$p_{it_R} = \frac{\sum_K P_{Kit_R} q_{Kit_R}}{\sum_K p_K q_{Kit_R}}. \tag{23}$$

[21] Nominal variables are rescaled in every year so that manufacturing wage in the US equals one.

Equations (22)-(23) are solved simultaneously for PPP price levels p_{it_R} and international prices p_K.

The restriction on prices in the reference year is then that the resulting relative real GDP per worker in the model equal their PWT equivalents. Specifically, real GDP per worker relative to the US for any country j must satisfy

$$\frac{\sum_K p_K q_{Kjt_R}/L_{jt_R}}{\sum_K p_K q_{KUSt_R}/L_{USt_R}} = \frac{y_{jt_R}}{y_{USt_R}}. \tag{24}$$

In addition, sectoral prices are normalized to one in the US in the reference year.[22]

To summarize this procedure, in the reference year we solve for sectoral prices $\left\{P_{Ajt_R},\, P_{M_{jt_R}},\, P_{Sjt_R}\right\}$ such that expenditure share equations (21) and relative real GDP equations (24) are satisfied for all countries.

In all other years equation (24) is replaced by a restriction that growth of real GDP per worker between 1995 and year t, evaluated in the model using reference year Geary-Khamis prices, must match the growth of real GDP per worker in the data for each country:

$$\frac{\sum_K p_K q_{Kit}/L_{it}}{\sum_K p_K q_{Kit_R}/L_{it_R}} = \frac{y_{jt}}{y_{jt_R}}. \tag{25}$$

For any year $t \neq t_R$ we therefore solve for sectoral prices $\left\{P_{Ajt},\, P_{M_{jt}},\, P_{Sjt}\right\}$ satisfying (21) and (25) for all countries present in the sample in year t.

The final output of the calculations described in this subsection is a set of sectoral wages and prices (and hence sectoral labor productivity levels by (18)) such that the model matches the data on sectoral employment levels, trade flows, nominal VA and aggregate real GDP for all years and all countries in the sample. The model does not match by design the data on sectoral labor productivity growth so these quantities can be used to discipline the remaining parameters of the model.

3.4 Calibration of Preference Parameters

In the previous subsection sectoral productivities were identified in part using expenditure shares stemming from the augmented CDES functional form of preferences. I now describe how preference parameters $\{\alpha_K,\, \gamma_K,\, \bar{c}_K\}_{K\in\{A,M,S\}}$ used in that calculation are chosen. In essence, I pick the preference parameters using the model's prediction for sectoral labor productivity growth over time. Under the assumption that the difference between productivity growth in the model and the data is the result of measurement error, I choose the preference parameters to minimize a GMM function of the sample correlation between this measurement error and observed variables.

Start with some *a priori* restrictions. To ensure that consumer preferences described by the CDES indirect utility function are well-behaved we need the following restrictions: $\alpha_K \geq -1$, $\gamma_K >$

[22]This normalization is a convenient choice of units in which goods are measured. It is equivalent to, e.g., setting the mean of productivity draws $T_{KUSt_R}^{1/\theta_K}$ in the US in the reference year to a particular value.

$0, \sum_K \gamma_K = 1$.[23] In line with the demand estimation tradition, I allow for subsistence consumption in agriculture $\bar{c}_A \geq 0$ but set $\bar{c}_M = \bar{c}_S = 0$. The equilibrium conditions in the reference year provide some further restrictions on the admissible parameter combinations. The expenditure shares equations (21) in the case of the US take the form

$$\frac{E_{KUS}}{\sum_k E_{kUS}} = \frac{1}{\sum_k E_{kUS}} \left[\bar{c}_K + \left(\sum_k E_{kUS} - \bar{c}_A \right) \frac{\gamma_K \left(\sum_k E_{kUS} - \bar{c}_A \right)^{\alpha_K}}{\sum_k \gamma_k \left(\sum_k E_{kUS} - \bar{c}_A \right)^{\alpha_k}} \right], \tag{26}$$

since I normalize $P_{KUS} = 1$ in the reference year as a choice of units. Preference parameters must be such that optimally chosen sectoral expenditures of U.S. households are consistent with expenditures E_{KUS} (which reflect the data and do not depend on preference parameters). Given $\{\alpha_A, \alpha_M, \alpha_S, \bar{c}_A\}$ preference weights $\{\gamma_A, \gamma_M, \gamma_S\}$ are pinned down by U.S. expenditure shares (26) for two sectors and a normalization $\gamma_A + \gamma_M + \gamma_S = 1$.

This leaves four consumer preference parameters $\{\alpha_A, \alpha_M, \alpha_S, \bar{c}_A\}$ to be chosen. Those parameters are determined using the general equilibrium predictions of the model for sectoral labor productivity growth. Those quantities are chosen for calibration because relative productivities play a prominent role in theories of structural transformation and they can be computed in a consistent way from the available data on employment, nominal value added and price deflators.[24]

The mechanics of the calibration are as follows.[25] For any candidate parameter vector $\omega = \{\alpha_A, \alpha_M, \alpha_S, \bar{c}_A\}$ I can follow the procedure described in the previous subsection and calculate sectoral labor productivities for each year in which country i is in the sample:

$$A_{it}(\omega) = \{A_{Ait}(\omega), A_{Mit}(\omega), A_{Sit}(\omega)\}.$$

Let t_l^i and t_f^i denote the last and first year that country i appears in the sample. Then calculate the annualized average log growth of A_{Kit} as $g_{Ki}(\omega) = \frac{1}{t_l^i - t_f^i} \log \left(\frac{A_{Kit_l^i}(\omega)}{A_{Kit_f^i}(\omega)} \right), \quad K \in \{A, M, S\}$. Analogous log growth of labor productivity computed from the data is denoted as g_{Ki}^d. Sectoral productivity series in the data are calculated using sectoral producer price deflators that are likely to suffer from measurement error. Consequently, there will necessarily be a discrepancy between the model's predictions for sectoral productivity growth and their empirical counterpart. That observation can be stated as

$$g_{Ki}^d = g_{Ki}(\omega_0) + \varepsilon_{Ki}, \quad K \in \{A, M, S\},$$

where ω_0 is the true data-generating value of the parameter vector. The key assumption is that ε_{Ki}

[23] See Jensen et al. (2011).

[24] I focus on long-run growth rather than on annual changes to best capture the secular trends associated with the process of structural change.

[25] More detailed description of the calibration algorithm can be found in Appendix B.

is a mean-zero random measurement error. The moment conditions I use can be written as

$$E\left[x_{Ki}^{(m)}\varepsilon_{Ki}\right]=0, \quad K\in\{A,\,M,\,S\}\,,\;m=1,...,3, \tag{27}$$

where the instruments x_K for sector K log productivity growth include a constant, log growth in sector K employment and log growth in expenditure share of sector K (all growth rates on an annualized basis). The sample size is $n=N^c$, where N^c is the total number of countries appearing in the sample. The vector of sample analogs of moment conditions (27) is given by

$$h_n(\omega)=\left[\frac{1}{n}\sum_{j=1}^{n}x_{Aj}^{(1)}\left(g_{Aj}^{d}-g_{Aj}(\omega)\right)...\frac{1}{n}\sum_{j=1}^{n}x_{Sj}^{(3)}\left(g_{Sj}^{d}-g_{Sj}(\omega)\right)\right]'.$$

I then seek the parameter vector that minimizes the following objective function:

$$\hat{\omega}=\arg\min_{\omega}\,n\cdot h_n(\omega)'\,\mathbf{W}h_n(\omega)\,. \tag{28}$$

I use an identity matrix as the weighting matrix ($\mathbf{W}=\mathbf{I}_9$) during the numerical optimization.[26]

4 Quantitative Assessment of Calibrated Model

In this section I summarize the implications of the calibrated model for patterns of demand, intersectoral labor distortions, sectoral labor productivities and comparative advantage. The purpose of this exercise is twofold. First, knowledge of these patterns helps in understanding the results of the counterfactuals in Section 5. Second, when possible I compare my results to the independently available evidence as a way of validating the model.

4.1 Properties of Demand and Model Fit

The first panel of Table 1 presents the calibrated values of preference parameters. More revealingly, the second panel of Table 1 shows the implications of those preference parameters for income, price and substitution elasticities (averaged across countries in the reference year). The first observation is that both income and substitution effects are important for matching the time series facts of structural transformation for a broad range of countries. The strength of nonhomotheticity is demonstrated by large differences in income elasticities across sectors. Importance of substitution channel is underlined by the fact that all elasticities of substitution are significantly below unity. In

[26] This calibration procedure can be thought of as a first stage of a nonlinear GMM estimation. However, since I do not calculate standard errors I prefer to call it calibration rather than estimation. Calculating standard errors would require making strong assumptions on the covariance structure of errors. Since I am not interested in testing hypotheses about preference parameters *per se* and the qualitative results of the paper are not very sensitive to modest changes in those parameters I focus on the calibration exercise only.

fact, σ_{AM} is negative, an outcome impossible with, e.g., CES preferences.[27] The second noteworthy observation is that demand for agricultural goods is very inelastic with respect to both income and prices (own and of other goods). Finally, to put the importance of the subsistence requirement $\overline{c}_A$ in perspective, satisfying that requirement takes on average 6.0% of total expenditure in 1995, with a low of 0.4% for Denmark and a high of 26.4% for India. For the poorest countries in the sample the calibrated model gives per capita consumption in agriculture not much higher than $\overline{c}_A$. On average $\overline{c}_A$ accounts for 57.8% of consumption per capita in agriculture in 1995.

I now present visually how well the model with those preference parameters fits the series on sectoral labor productivities and relative prices over longer periods of time. The first three panels of Figure 1 show growth rates of labor productivity over the entire sample period on an annualized basis, which are the quantities targeted by the calibration strategy described in the previous section.[28] The correspondence between the model and the data is pretty close, with correlation coefficient 0.81 for A_A , 0.85 for A_M and 0.92 for A_S.

The last two panels of Figure 1 present similar plots for the annualized growth rates of relative prices. Here the fit appears a little worse with correlation of 0.60 for P_A/P_M and 0.57 for P_S/P_M. Given the way data is constructed, however, there is a mechanical relationship between the measurement error in growth of productivities and relative prices. For example, the error in log growth of P_A/P_M is just the difference in errors in log growth of A_M and A_A. Thus less good fit for relative prices is to be expected.

4.2 Intersectoral Labor Distortions

Distortions to the allocation of labor across sectors take a prominent role in my analysis. In this subsection I summarize the patterns of wedges observed in my dataset.

Recall that the wedge in agriculture (services) is measured simply as value added per worker in agriculture (services) relative to value added per worker in manufacturing. Figure 2 plots the wedges in agriculture and services against real income in the reference year 1995. Substantial variation in the level of wedges across countries can be seen in that figure. A natural question that arises is whether wedges are related to aggregate productivity, as could be expected if they represent distortions. While the overall picture is quite noisy, some patterns can be distilled from the data presented in Figure 2. First, the levels of ξ_{Ai} are below unity for all countries except for Hungary, with the geometric mean of 0.38. Measured in domestic prices, VA per worker generated in agriculture is universally low relative to industry. That is not true for services in general: while the geometric mean of ξ_{Si} is below unity at 0.83, there are many countries where a worker generates more value in services than in manufacturing. Looking at the relationship between the level of

[27] The extra flexibility allowed by CDES preferences does matter. Calibrating a version of the model with augmented CES preferences would lead to a corner solution with Leontief preferences (equivalent to $\alpha_A = \alpha_M = \alpha_S = -1$) which implies no substitution possibilities across sectors whatsoever.

[28] Note that since countries enter and leave the sample at various dates the time interval over which the changes in Figure 1 are calculated vary by country.

wedges and aggregate productivity, the correlation between ξ_{Ai} and the logarithm of real GDP per worker is 0.53 and statistically significant. In contrast, the wedge in services is uncorrelated with income in the reference year. However, since values both higher and lower then one represent distortions in the model, it is more appropriate to look at the behavior of the deviations of wedges from unity over the income distribution. Defining $\zeta_{Ki} = |\xi_{Ki} - 1|$ we find a statistically significant negative correlation (-0.54) between ζ_{Ai} and real income. Moreover, the negative correlation (-0.27) between deviations in services and real income is now significant at the 0.1 level.

To investigate the correlations between the level of wedges and aggregate productivity beyond the reference year, I estimate separately for agriculture and services the following equation:

$$x_{Kit} = \alpha_K \ln y_{it} + \delta_{Kt} + \varepsilon_{Kit},$$

where $\ln y_{it}$ is the logarithm of real GDP per worker, δ_{Kt} is a year fixed effect and x_{Kit} is either a wedge level ξ_{Kit} or its deviation from unity ζ_{Kit}. Results presented in columns 1-4 of Table 2 show the same pattern as in the reference year: the level of the agricultural wedge is positively correlated with income and the magnitude of the distortion in both sectors is negatively correlated with income. These correlations between distortions and income are cross-sectional in nature: adding country fixed effects to columns 1-4 would render income statistically insignificant in all four specifications.

Moving from the cross-sectional patterns of wedges to their evolution over time, I regress ξ_{Kit} and ζ_{Kit} on country dummies and a time trend. Results reported in columns 5-6 of Table 2 indicate the presence of a secular downward trend in the level of wedges over time within countries, both for agriculture and services. Since wedges in agriculture are almost always below one, a downward trend implies that distortions between agriculture and manufacturing are getting larger over time on average. Column 7 confirms the presence of a positive trend in ζ_A. In contrast, since wedges in services are distributed on both sides of unity, a downward trend in the level of ξ_S (column 6) is consistent with a lack of statistically significant trend in the magnitude of deviation from unity ζ_S (column 8).

To conclude the discussion of wedges, I briefly present some evidence on dispersion of distortions over time. Since the composition of the sample changes over time I restrict the attention to 21 countries that are in the sample in every year between 1970-2005.[29] Figure 3 plots the coefficient of variation of ξ_{Ai} and ξ_{Si} for those countries over time. Dispersion of wedges in agriculture is steadily falling until mid-1990s when the trend reverses. For wedges in services the dispersion is relatively stable until the late 1980s when it starts on an upward trajectory.

[29]Patterns documented in Table 2 are robust to focusing on this balanced panel.

4.3 Sectoral Labor Productivity

I now turn to the cross-sectional predictions of the model for labor productivity at a sector level. Figure 4 summarizes the patterns of calibrated sectoral productivity levels in the reference year 1995. To construct that figure I first divide all countries by the quartile of real income per worker (which the model matches by design). I then calculate the mean productivity level for each sector and for aggregate productivity within each quartile of aggregate productivity. Figure 4 plots these means relative to the the average among the highest-income group of countries. Some general patterns can be gleaned from that figure.

First, cross-country differences in agricultural labor productivity are much larger than differences in aggregate productivity. For example, the ratio of aggregate productivity between the lowest and the highest quartile in the sample is equal to 0.11 but the corresponding ratio for agricultural labor productivity is only 0.04. Conversely, differences in labor productivity in services are smaller than aggregate productivity differences. Continuing with the example, a country in the lowest quartile is on average 0.16 times as productive in services as an average country in the highest quartile of income per worker. Manufacturing presents a mixed case - it is relatively more productive then the aggregate economy for the poorest countries but it lags the aggregate productivity in middle income countries. Calculating the dispersion of labor productivity across all countries in 1995, the coefficient of variation is 1.31, 0.71, 0.57 and 0.65 for agriculture, manufacturing, services and aggregate labor productivity, respectively.

A related observation is that not only is productivity in agriculture more dispersed than aggregate productivity, but the gap between productivity in agriculture and in the overall economy is decreasing in income. The ratio of labor productivity in agriculture relative to aggregate productivity is 0.34, 0.57, 0.64 in the first, second and third quartile of real income distribution (relative to the highest quartile). For services we have the opposite behavior (1.56, 1.19, 1.10) while there is no monotonic relationship between manufacturing productivity relative to aggregate productivity and income.[30]

The patterns of sectoral labor productivity predicted by the model are broadly consistent with the accumulated body of evidence. The fact that differences in labor productivity are much higher in agriculture than in non-agriculture is now well established, see e.g. Restuccia et al. (2008) and Caselli (2005). Restuccia et al. (2008) calculate that in 1985 the GDP per worker was 34 times higher in the richest 5% of the countries in the world than in 5% of the poorest. That number could be decomposed into 78-fold difference in agricultural labor productivity compared to only 5-fold difference in non-agriculture.

Moving beyond the agriculture - non-agriculture split, the direct estimates of sectoral labor productivity are more scarce since comparing productivity levels in services is notoriously difficult. The

[30] These numbers can in part reflect the composition effect since, e.g., services account for a larger share of the aggregate economy in richer countries.

conventional wisdom, tracing back to the Samuelson - Balassa effect, is that productivity differences in tradables are higher than in nontradables ("haircuts"). That statement is often strengthened to a claim that productivity differences in manufacturing are higher than in services. Findings of a recent study by Duarte and Restuccia (2010) go against that second form of conventional wisdom. In particular, their model predicts cross-country dispersion of productivity in services that is much higher than in industry. My calibration generates modestly higher dispersion in manufacturing, going along with the conventional wisdom. One explanation for difference in findings is that my model incorporates additional margins (international trade and intersectoral distortions) that have an impact on the calibration of sectoral productivities. Duarte and Restuccia defend their findings by referring to the results of micro-based studies that often find large differences across countries in narrowly-defined service activities. These studies, summarized by Baily and Solow (2001), are not necessarily easily translatable to the aggregated service sector, however. Micro studies concentrate on specific market services and, as Inklaar and Timmer (2012) demonstrate, there are pronounced differences in cross-country patterns for market and non-market services. To the extent that non-market services such as education constitute a major part of the service sector and productivity differences within that group are small, overall cross-country differences in labor productivity in services might be small despite being large in a subset of market services. As further evidence in favor of the conventional wisdom, Herrendorf and Valentinyi (2012) find that dispersion of TFP in the sectors I classify as manufacturing are higher than TFP dispersion in services.

To go beyond discussing broad qualitative patterns, I compare sectoral productivity levels from the model with data for a subsample of countries for which I can find the necessary data. Specifically, I use the information on value added and producer price based PPPs in 1997 from GGDC Productivity Level Database (Inklaar and Timmer (2008)) to calculate measures of labor productivity that are comparable across countries. That calculation is possible for 23 countries that are both in my sample and in PLD. Relative to my full sample for 1997 the subsample I use in this calculation is restricted mostly to the OECD countries. Within that group the model generates higher dispersion of labor productivity in agriculture than computed from PLD: the coefficient of variation is 0.97 in the model and 0.62 in the data. For the other two sectors the dispersion measures are very close: the coefficient of variation in manufacturing is 0.47 in the model and 0.47 in the data while the corresponding numbers for services are 0.23 and 0.18. Looking directly at the levels rather than dispersion, the correlation between labor productivity in the model and in the data derived from PLD is 0.80 in agriculture, 0.91 in manufacturing and 0.80 in services.

In this subsection I concentrated on the cross-sectional predictions of the model for sectoral labor productivity in or around the reference year. Given that these predictions are broadly in line with the available evidence and that the growth rates of labor productivity are fitted well by the model, levels of labor productivity delivered by the model in other years are also close to the data.

4.4 Comparative Advantage

An implication of the patters discussed in previous section is that poor countries have low labor productivity in agriculture relative to manufacturing. Yet the same poor countries that are relatively unproductive in agriculture have the highest shares of employment devoted to that activity. A number of explanations exist for this well-established feature of the world: the role of food as a basic subsistence need going back to Schultz (1953) and recently combined with sorting of heterogeneous workers across sectors by Lagakos and Waugh (2011), lack of human capital needed in manufacturing as in Caselli and Coleman (2001), investment distortions forcing people into home-production in agriculture as in Gollin et al. (2004), to name just a few. Not all of these theories are equally compelling in the open economy setting, however. The question that a successful theory must answer is why don't poor countries simply import more food if they are so unproductive in agriculture? In the data in fact we see virtually no relationship between income per capita and net exports relative to value added at a sector level. In my model, similarly to Tombe (2012), intersectoral labor can reconcile the trade and productivity patterns.

Before I discuss the patterns of comparative advantage in more detail, I need to specify the values of the parameters θ_A, θ_M governing the dispersion of Frechet productivity draws. I do not need to take a stand on the magnitude of these parameters during the calibration of the model but they play a role in the calculations of comparative advantage measures and in counterfactual exercises in the next section. For dispersion in manufacturing I choose $\theta_M = 5$, a value between the 4.12 estimated by Simonovska and Waugh (2011) and 8.28 which is often used as benchmark following the original Eaton and Kortum (2002) specification. Estimates for agriculture are scarce, hence I also set $\theta_A = 5$ as a focal number close to 4.8 estimated by Xu (2011), the only estimate of which I am aware.

In Section 4.3 I report the results about sectoral labor productivity A_{Ki} as this measure is consistent with the object of study in the macro-development literature. In the context of international trade it is useful to also look at different quantities. A purely technological measure of comparative advantage in agriculture can be defined as $T_{Ai}^{1/\theta_A}/T_{Mi}^{1/\theta_M}$, where recall that T_{Ki}^{1/θ_K} is proportional to the mean of the productivity draws in county i and sector K. One can show that

$$\frac{T_{Ai}^{1/\theta_A}}{T_{Mi}^{1/\theta_M}} \propto \frac{A_{Ai}^{\beta_A}\pi_{Aii}^{1/\theta_A}}{A_{Mi}^{\beta_M}\pi_{Mii}^{1/\theta_M}}. \tag{29}$$

Thus this technological measure of comparative advantage strips the relative labor productivity of the selection effect due to international trade and adjusts for the multiplier effect coming through the use of intermediates. The left panel of Figure 5 plots measure (29) for the reference year against the logarithm of real income. There is an overall increasing relationship, with the statistically significant correlation of 0.62. Consistent with earlier findings for relative labor productivity A_{Ai}/A_{Mi}, poor countries have technological comparative advantage in manufacturing.

Relative technology is not the only force determining patterns of international trade in my model, however. At the heart of the Ricardian logic lies the notion of comparative cost. A measure that captures competitiveness of a country in agriculture relative to manufacturing is given by

$$\frac{\left(T_{Ai}c_{Ai}^{-\theta_A}\right)^{1/\theta_A}}{\left(T_{Mi}c_{Mi}^{-\theta_M}\right)^{1/\theta_M}} \propto \frac{A_{Ai}\pi_{Aii}^{1/\theta_A}}{A_{Mi}\pi_{Mii}^{1/\theta_M}}\xi_{Ai}^{-1}. \tag{30}$$

This measure adjust the purely technology-based quantity by taking account of input cost differentials across sectors. In particular, the RHS of (30) contains the inverse of the agricultural wedge. As discussed in Section 4.2, producers in agriculture in poor countries face lower wages relative to manufacturing producers, compared to producers in rich countries. Since ξ_{Ai} is relatively low in poor countries, the cost-adjusted relative competitiveness (30) will be relatively higher in poor countries than the technological-only measure (29). The right panel of Figure 5 illustrates the comparative cost in in the reference year. It shows no statistically significant correlation with aggregate productivity. Once we control for lower relative wages in agriculture in poor countries, rich countries do not necessarily emerge as having relative cost advantage in agriculture.

The cross-sectional pattern seen in Figure 5 generalizes to the regression analysis on the entire sample. In Table 3 I report the results of regressing the two measures of comparative advantage on aggregate productivity and year dummies. Rich countries show statistically significantly higher levels of technological comparative advantage in agriculture (column 1) but their competitiveness advantage is gone once we adjust for higher distortions in poor countries (insignificant coefficient on income in column 2).

To further illustrate that both technology and distortions are quantitatively important in determining comparative advantage, Table (4) shows the variance decomposition of the logarithm of the relative competitiveness measure (30) (calculated for the whole sample). The dispersion in relative labor productivity (A_{Ai}/A_{Mi}) is almost twice as large as dispersion in wedges $\left(\xi_{Ai}^{-1}\right)$ and there is a strong negative correlation between the two quantities.

5 Counterfactuals

In this section I use counterfactual simulations of the calibrated model to answer the core question of the paper: how do domestic distortions affect the welfare gains from trade? In addition, I explore the implications of intersectoral labor distortions for trade policy and assess the importance of distortions and trade for the process of structural change. I begin by describing how exactly the counterfactual scenarios are calculated.

For any variable x in the original equilibrium let x' denote its counterfactual value and let $\hat{x} = x'/x$ denote the proportional change. In the counterfactual exercises I consider the impact on equilibrium outcomes of exogenous changes in wedges $\left\{\hat{\xi}_{Ai}, \hat{\xi}_{Si}\right\}$, trade deficits relative to GDP

$\left\{\hat{\delta}_i\right\}$, technological parameters $\left\{\hat{T}_{Ai},\, \hat{T}_{Mi},\, \hat{B}_{Si}\right\}$ and trade costs $\{\hat{\tau}_{Aji},\, \hat{\tau}_{Mji}\}$.

Solving for counterfactual equilibrium boils down to finding new manufacturing wages $\{w'_{Mi}\}$ and new labor allocations $\{L'_{Ai},\, L'_{Mi}, L'_{Si}\}$. Once we know manufacturing wages, we also know the labor costs in other sectors since $\hat{w}_{Ki} = \hat{\xi}_{Ki}\hat{w}_{Mi}$. Simple calculations show that the change in price between the benchmark and the counterfactual can be expressed as:

$$\hat{P}_{Kj} = \left[\sum_i \pi_{Kji} \left(\hat{w}_{Ki}^{\beta_K} \hat{P}_{Ki}^{1-\beta_K}\right)^{-\theta_K} \hat{T}_{Ki}\hat{\tau}_{Kji}^{-\theta_K}\right]^{-\frac{1}{\theta_K}}, \quad K \in \{A, M\}. \tag{31}$$

Given changes in wages, the system of equations (31) can be solved for changes in prices in tradable sectors. In nontradable services we simply have

$$\hat{P}_{Sj} = \frac{\hat{w}_{Sj}}{\hat{B}_{Sj}^{1/\beta_S}}.$$

With the knowledge of changes in wages and price levels, the counterfactual trade shares are given by:

$$\pi'_{Kji} = \frac{\pi_{Kji}\hat{T}_{Ki}\left(\hat{w}_{Ki}^{\beta_K}\hat{P}_{Ki}^{1-\beta_K}\right)^{-\theta_K}\hat{\tau}_{Kji}^{-\theta_K}}{\sum_m \pi_{Kjm}\hat{T}_{Km}\left(\hat{w}_{Km}^{\beta_K}\hat{P}_{Km}^{1-\beta_K}\right)^{-\theta_K}\hat{\tau}_{Kjm}^{-\theta_K}}.$$

Next, given counterfactual wages, prices, deficits relative to GDP and labor allocation, the counterfactual final expenditure adjusted for subsistence requirements is

$$\tilde{X}_i^{F\prime} = (1+\delta'_i)\sum_K w'_{Ki}L'_{Ki} - \sum_K \bar{c}_{Ki}P'_{Ki}.$$

Making use of the intermediate results stated above, the solution algorithm finds counterfactual manufacturing wages $\{w'_{Mi}\}$ and labor allocations $\{L'_{Ai},\, L'_{Mi}, L'_{Si}\}$ such that:

1. Counterfactual goods markets clear. The market clearing conditions (9)-(10) can be written in terms of counterfactual values as:

$$w'_{Ki}L'_{Ki} = \sum_j \pi'_{Kji}\left\{(1-\beta_K)\,w'_{Kj}L'_{Kj} + \beta_K L_j P'_{Kj}\left[\bar{c}_K + \frac{\gamma_K\left(\frac{\tilde{X}_j^{F\prime}/L_j}{P'_K}\right)^{\alpha_K+1}}{\sum_k \gamma_k\left(\frac{\tilde{X}_j^{F\prime}/L_j}{P'_k}\right)^{\alpha_k}}\right]\right\}, \quad K\in\{A,\, M\}$$

$$w'_{Si}L'_{Si} = L_iP'_{Si}\left[\bar{c}_S + \frac{\gamma_S\left(\frac{\tilde{X}_i^{F\prime}/L_i}{P'_S}\right)^{\alpha_S+1}}{\sum_k \gamma_k\left(\frac{\tilde{X}_i^{F\prime}/L_i}{P'_k}\right)^{\alpha_k}}\right].$$

2. Counterfactual labor market clears:

$$L'_{Ai} + L'_{Mi} + L'_{Si} = L_i.$$

In some counterfactuals I consider closing economies to international trade. That is equivalent to setting $\pi'_{Kii} = 1$ and $\pi'_{Kji} = 0$ for $i \neq j$ in the expressions above.

5.1 Cross-Sectional Results

In this subsection I summarize the cross-sectional results, showing the effect of counterfactual changes on equilibrium outcomes in a given year. In particular, I focus on the implications of international trade for welfare and sectoral labor allocation and I show the role played by labor wedges in generating those results. To measure welfare changes between different equilibria, I use percentage increase in expenditure required to make the representative agent indifferent between the original equilibrium and the new one (i.e., equivalent variation relative to the original expenditure level). Results are reported for the reference year 1995 but the patterns I highlight are robust throughout the sample period.

The model is calibrated to match the overall trade deficit relative to country's GDP in every year. The first counterfactual exercise involves eliminating aggregate trade deficits in all countries, that is setting $\delta'_i = 0$.[31] On top of being interesting in its own right, there is another reason why this counterfactual is presented first. Some subsequent experiments involve closing economies to international trade in order to illustrate differential responses to some hypothetical change under autarky and with trade. Since closed economies cannot have trade deficits and trade deficits have a direct impact on consumers' welfare, the open economies will have the aggregate deficits removed as well to make sure that any welfare differences are not due to the divergence of final expenditure from income that international trade enables. The starting point for most comparisons will therefore be not the benchmark equilibrium calculated in the previous section but the counterfactual equilibrium that eliminates aggregate deficits.

The first panel of Figure 6 plots the percentage increase in welfare due to eliminating aggregate trade imbalances against the scale of these deficits in 1995. There is a tight inverse relationship: the burden of eliminating trade deficit is close to proportional to the size of the required transfer.[32] Panels 2-4 show the corresponding changes in sectoral labor shares. Eliminating imbalances in deficit countries requires reallocating resources from nontradable services to tradable sectors. For example, to eliminate the U.S. deficit of 1.8% of GDP, 1.3% of the labor force would move from services to manufacturing and 0.2% from services to agriculture. As a result of the transfer welfare of American consumers would fall by 1.7%. These patterns are similar to what Dekle et al. (2008) find using a model with one tradable sector without distortions, which suggests that the equilibrium without aggregate trade imbalances can safely be used as a starting point for further counterfactuals.

[31] Trade need not to be balanced sector-by-sector, however. Sectoral trade deficits adjust endogenously to be consistent with balanced aggregate trade.

[32] For a few countries with largest trade imbalances the counterfactual equilibrium can therefore differ substantially from the observed benchmark equilibrium. E.g., after eliminating surplus of 15.1% of GDP in Ireland, labor previously generating this surplus (implicitly equipped with other factors, some of them foreign-owned in reality) would on average be producing for domestic consumption, increasing welfare of Irish consumers by 16.1%.

Gains From Trade

In this subsection I demonstrate the quantitative importance of intersectoral distortions for the magnitude of the welfare gains from trade. The first column of Table 5 lists the baseline gains from trade GFT, expressed in percentage terms, calculated using my model for all countries present in the sample in 1995.[33] For comparison, the last columns shows the corresponding gains from trade GFT^{ND} that would be obtained in a standard model that abstracts from intersectoral distortions.[34]

Measured by simple mean across countries, the standard model overstates the gains from trade: the mean of GFT^{ND} is 6.84% but taking distortions into account brings down the number for GFT to 4.73%. Naturally, these means mask a wide heterogeneity at a country level. In particular, it need not be the case that gains from trade are lower in the presence of distortions. In a second best world with frictions any outcome is possible and, in fact, for almost half of countries gains from trade are higher in the model with domestic distortions. It need not even be the case that the most distorted countries have lower gains from trade, as an example of heavily distorted China illustrates.

To better understand the impact of domestic distortions, it is useful to start with the following approximation to GFT, based on (13):

$$GFT_j \approx \widetilde{GFT}_j \equiv 1 - \underbrace{\frac{\left(\sum_K \xi_{Kj} L^A_{Kj}\right)}{\left(\sum_K \xi_{Kj} L^T_{Kj}\right)}}_{\Upsilon_j} \underbrace{\left[\sum_K e^T_{Kj} \left(\pi_{Kjj}^{-\frac{1}{\theta_K}\frac{1}{\beta_K}}\right)^{-\alpha}\right]^{\frac{1}{\alpha}}}_{\widetilde{LFA}^{ND}_j}, \tag{32}$$

where $\alpha = \sum_K \alpha_K e^T_K$ is the expenditure-weighted average of CDES preference parameters α_K. $\widetilde{GFT}$ essentially approximates the nonhomothetic CDES preferences with homothetic CES with elasticity of substitution $1 + \alpha$. Numerically, $\widetilde{GFT}$ provides an excellent approximation to GFT.[35] $\widetilde{GFT}$ can be decomposed into the labor reallocation channel Υ and the term $\widetilde{LFA}^{ND}$ denoting the losses from moving to autarky in a model without intersectoral distortions and with CES preferences. Writing $GFT^{ND} \equiv 1 - LFA^{ND}$ and using a similar CES approximation leads to $LFA^{ND} \approx \widetilde{LFA}^{ND}$. Therefore the relationship between gains from trade in models with and without wedges can be

[33] Details of the calculation: let T and A superscripts denote variables in the trade equilibrium (with aggregate deficits removed) and in autarky equilibrium, respectively. I first compute the per capita expenditure level $\check{E}_j$ at which consumers in country j would be indifferent between staying in trade equilibrium or moving to autarky by solving $V\left(P^T_{Aj}, P^T_{Mj}, P^T_{Sj}, \check{E}_j\right) = V\left(P^A_{Aj}, P^A_{Mj}, P^A_{Sj}, E^A_j\right)$. Then I define the losses from moving to autarky as $LFA_j \equiv \check{E}_j / E^T_j$ and the gains from trade as $GFT_j \equiv 1 - LFA_j$. GFT_j reported in Table 5 are expressed in percentage terms.

[34] In order to calculate GFT^{ND}, I recalibrate the model to match the data on sectoral VA and trade flows, similarly as in my baseline calibration. However, in the absence of labor wedges the standard model does not match sectoral employment levels because employment shares are now determined by VA shares. I keep preference parameters at the values from the baseline calibration.

[35] Regression of GFT on $\widetilde{GFT}$ gives a very precisely estimated coefficient of 1.02 and an R^2 of 0.999 in 1995. The corresponding means are 4.73% and 4.57%.

very well approximated as (c.f. (12)):

$$GFT_j \approx 1 - \Upsilon_j \left(1 - GFT_j^{ND}\right).$$

The gains from trade will be overstated by the standard model if $\Upsilon_j > 1$, i.e. if after opening to trade labor moves towards sectors in which producers face relatively low wages. Since those sectors would have inefficiently high employment in autarky to begin with, trade tends to magnify the effect of domestic intersectoral distortions in these cases. Recall from Section 4.2 that $\xi_A < 1$ almost universally. Given this empirical pattern of wedges, $\Upsilon > 1$ occurs primarily if employment in agriculture is larger in the trade equilibrium than in the hypothetical autarky. This can be seen in Table 5 by looking at column 7, which reports Υ, and columns 2-4 which report the response of sectoral labor shares to opening to trade.

The labor reallocation measure Υ_j as written above depends on the unobserved counterfactual autarky allocation. However, in the CES approximation Υ can be expressed only in terms of data observed in the trade equilibrium. Let δ_{Kj}^T denote the ratio of trade deficit in sector K to GDP in country j. In Appendix C.1 I derive the expression for Υ in terms of wedges ξ_K, deficit intensities δ_K^T and variables used to calculate $\widetilde{LFA}^{ND}$. In the empirically relevant case when sectoral expenditure shares do not change much between autarky and trade equilibria, the formula I obtain implies that $\Upsilon > 1$ if $(1 - \xi_A)\, \delta_A^T < 0$. Since $\xi_A < 1$ overwhelmingly in the data, frictionless model would overpredict the gains from trade for countries with large agricultural surpluses relative to their GDP (and consequently large manufacturing deficits with balanced aggregate trade). The negative relationship between the sign of δ_A^T and value of Υ can be seen in Table 5 by comparing columns 5 and 7. To illustrate this point more clearly, Figure 7 plots the mean gains from trade in the model with and without distortions by quartile of agricultural deficit relative to GDP in 1995. The standard model generates a slightly U-shaped pattern. In that model gains from trade depend only on how much a country trades: $\widetilde{LFA}^{ND}$ depends on sectoral trade intensities π_{Kjj} weighted by sectoral expenditure shares. Since countries with large deficits in either agriculture or manufacturing tend to trade a lot, GFT^{ND} are high for countries at both ends of the spectrum of agricultural deficit to GDP ratio. This is in stark contrast to gains from trade in the baseline model with distortions, which on average rise in the agricultural deficit to GDP ratio. Consequently, the difference between GFT and GFT^{ND} is robustly rising with the magnitude of observed agricultural deficits. For the first quartile of agricultural deficit to GDP ratio, GFT are on average 8.9 p.p. lower than GFT^{ND} in 1995, while for the highest quartile they are 1.5 p.p. higher. Put bluntly, the existing workhorse trade models significantly overpredict the gains from trade for large net exporters of agricultural goods, while underpredicting the gains from trade for manufacturing net exporters. In the second-best world with domestic intersectoral distortions gains from trade depend not only on how much you trade; what you export matters as well.

For some countries in the sample my model predicts overall losses from trade. This can happen in my framework if the losses from perverse labor reallocation outweigh the standard gains from the availability of cheaper foreign goods. In contrast, in all main workhorse models of international trade absolute gains from trade are assured.[36] While losses from trade are not common (less than 20% of observations), my calculations show that they can occur in a realistically calibrated quantitative model.[37]

The formula for $\widetilde{GFT}$ given in (32) can be also used to shed light on the importance of distortions for gains from trade in another way. The decomposition of the variance of the logarithm of $\Upsilon \cdot \widetilde{LFA}^{ND}$ for 1995 shows that 0.62 of the variance can be attributed to the variance of the logarithm of the labor reallocation component Υ, 0.48 to the variance of the logarithm of the no-distortions component $\widetilde{LFA}^{ND}$, and -0.10 to their covariance. The contribution of Υ is somewhat mitigated if the extreme results are omitted from the analysis. Ignoring the highest 5% and lowest 5% of the GFT, the contribution of Υ is 0.53, $\widetilde{LFA}^{ND}$ is responsible for 0.80 of the variance, and -0.33 can be attributed to their covariance. But overall the labor reallocation channel emphasized in this paper is clearly quantitatively important for understanding the cross-sectional variance of the gains from trade.

I conclude this subsection by discussing two caveats. First, while calculating counterfactual autarky equilibria I keep the labor wedges constant. This implicitly assumes that the intersectoral distortions that the wedges capture are not affected by the trade regime. Second, the quantitative importance of distortions for the gains from trade clearly depends on the magnitude of distortions. To check the sensitivity of my results, I recalculate the gains from trade for various levels of wedges.[38] For concreteness, I replace the baseline wedge ξ^0_{Kj} with a weighted average of ξ^0_{Kj} and unity (no distortion) by setting $\xi_{Kj} = \chi\xi^0_{Kj} + (1 - \chi)$, simultaneously for both wedges and all countries. Results for a few representative countries for $\chi \in \{1, 0.75, 0.5, 0.25, 0\}$ are presented in Table 6. The first ($\chi = 1$) and last ($\chi = 0$) column correspond to the first and last column of Table 5, while the columns in between reflect intermediate levels of wedges. Two observations are worth emphasizing. First, absolute losses from trade require distortions close to the baseline level. If distortions are only half as large as in the baseline calibration then all countries in the sample in 1995 would benefit from trade. Second, the finding that the frictionless model overstates the welfare gains from trade for agricultural net exporters is robust. With distortions half as large as in the baseline case the model completely abstracting from intersectoral distortions would still overpredict the gains from trade for the countries in the first quartile of agricultural deficit to GDP ratio by

[36] If $\Upsilon_j = 1$ then positive gains from trade are assured since $\widetilde{LFA}^{ND}_j < 1$ necessarily.

[37] In the model there are two frictions: intersectoral labor distortions and trade costs. There is a qualitative difference between them in that the former is a pure distortion while the latter is a real cost. This distinction is not critical for the possibility of losses from trade: in theory, a country with domestic intersectoral distortions might lose from costless international trade.

[38] I resolve the model holding preference parameters constant as in the baseline calibration. See also footnote 34. Note that this calculation assumes alternative levels of distortions to be present in the actual world. A distinct though experiment would be to solve the model under baseline wedges and then use counterfactual simulations with respect to wedges to ask what the gains from trade would be if the wedges had changed.

almost 2 p.p. on average.

Trade Policy

Moving away from the somewhat abstract comparisons with autarky and into a more policy-relevant area, I now focus on the effects of local changes in trade frictions.

Since I do not have the data on bilateral tariffs over my sample period, the baseline model is calibrated assuming only iceberg transport costs.[39] In order to study the effects of realistic trade policies, the model can be extended by treating the bilateral trade cost τ_{Kji} as consisting of an iceberg component d_{Kji} and an ad-valorem tariff rate t_{Kji}, with $\tau_{Kji} = d_{Kji}(1 + t_{Kji})$. In Appendix C.2 I sketch such an extension of the model under the assumption that net tariff revenue is redistributed lump-sum to households. My framework can be therefore used to perform policy counterfactuals of the following form: starting in the benchmark equilibrium (with real trade costs only), what are the effects of imposing import tariffs or subsidies?

First I consider unilateral changes in tariffs. Figure 8 plots the response of welfare to tariffs and subsidies imposed in agriculture or manufacturing individually for a few selected countries, where the same tariff/subsidy rate is applied regardless of the foreign source. Each country of those presented would benefit from unilaterally imposing a tariff in manufacturing and each would gain from subsidizing imports in agriculture. These partial results carry through to a formal optimization problem of finding optimal tariffs (t_{Aj}, t_{Mj}) allowed to differ between sectors but not across sources. Table 7 shows the optimal trade policy and increase in welfare relative to no-tariff benchmark for countries from Figure 8. In all cases it would be unilaterally optimal to impose a tariff on manufactured goods and subsidize agricultural imports. The intuition behind this pattern is as follows: intersectoral distortions typically act as if they were depressing wages faced by producers in agriculture ($\xi_{Aj} < 1$ in almost all countries), leading to higher employment in that sector than optimal. It is therefore optimal to reallocate some labor from agriculture to manufacturing. Trade policy can be used to undo some of the labor misallocation - taxing manufacturing imports and subsidizing agricultural imports achieves the desired reduction in agricultural employment. In terms of magnitude, the benefits of unilaterally choosing optimal tariffs for a rich and large country like the US are small at 0.5% of welfare. The stakes are much higher for developing countries - for example China can gain up to 27.2% from pursuing optimal trade policy.

Trade policy favoring domestic manufacturing often has negative effect on the welfare of other countries, however. International spillovers of domestic policy can be quantitatively nontrivial. As an illustration, consider the effects of India unilaterally introducing a 20% manufacturing tariff. Welfare gains to Indian households from such tariff amount to 1.9%. All other countries in the world lose from the Indian protectionism, with six countries experiencing losses of more than 0.1%

[39] Taking into account tariff revenue would affect the calculation of sectoral expenditures, and hence sectoral prices and productivities, given my calibration strategy. However, to the extent that sectoral tariff revenue is small relative to the overall sectoral expenditure, the impact of incorporating tariffs on productivity estimates would be very limited.

of welfare. The biggest losers are other poor countries geographically close to India: Sri Lanka, Vietnam, Thailand, Bangladesh, Indonesia and Malaysia. Imposing a manufacturing tariff causes the reallocation of Indian labor away from agriculture, but the resulting loss of agricultural production must be made up by increased imports in agriculture. Agricultural employment thus rises in India's trading partners, with relatively larger increase in countries for which India is a relatively important destination for agricultural exports. These tend to be geographically close countries. Since these countries also tend to have small ξ_A, an increase in agricultural production is associated with relatively large welfare losses. This example illustrates that manufacturing protectionism is a beggar-thy-neighbor policy and it is likely to particularly hurt neighboring poor counties.

What would optimal tariffs be in the absence of labor distortions? Calculations using both no-wedges counterfactual as a starting point and the model recalibrated without distortions suggest a similar pattern. Unilaterally, it would be optimal for countries to impose a tariff of similar magnitude in both sectors (about 20%). The optimality of a small positive tariff in one-sector Eaton and Kortum model was shown by Alvarez and Lucas (2007). Since the size of the optimal tariff is related to the dispersion parameter θ and in my calibration $\theta_A = \theta_M$, it is not surprising that there is little incentive to distort allocation of labor by setting different tariff rates.

I now present reduced form evidence consistent with the finding that due to intersectoral distortions developing countries would want to protect their manufacturing sector rather than agriculture. Looking directly at statutory tariff rates would be problematic due to the abundance of non-tariff measures, particularly in agriculture. To measure the relative trade protection in agriculture and manufacturing I therefore use the recently compiled Distortions to Agricultural Incentives (DAI) database, described in Anderson and Nelgen (2012). DAI database constructs implied levels of protection for individual goods by comparing border prices and domestic producer prices. These individual Nominal Rates of Assistance (NRA) items are then aggregated to provide Relative Rate of Assistance (RRA), which summarizes the relative protection offered to producers of tradables in agriculture and nonagriculture.[40] Table 8 presents the results of regressing RRA on the logarithm of income per worker using a pooled sample. Column 1 controls for year fixed effects and column 2 adds country fixed effects. In both specifications income per worker is significant, indicating that poor countries in fact offer more trade protection to manufacturing than to agriculture, compared to rich countries. Moreover, for the poorest countries in the sample NRA in agriculture is often negative, further suggesting that trade policy has a strong anti-agriculture bias. My framework can rationalize the existence of such pro-manufacturing bias of trade policy in developing countries.[41]

The main message of this subsection is thus that the presence of intersectoral distortions might affect the benefits of pursuing trade policies in a quantitatively important way. In particular,

[40] Loosely speaking, Nominal Rate of Assistance for good k is calculated as $NRA_k = \frac{\text{producer price}_k}{\text{border price}_k}$. Relative Rate of Assistance is then defined as $RRA = \frac{1+NRA_{agr}}{1+NRA_{nonagr}} - 1$.

[41] Of course, there are other potential explanation for the manufacturing bias, such as political economy considerations from which this paper abstracts.

developing countries might have strong incentives to shelter their manufacturing sector. These results should not be treated as policy recommendation for protectionism in manufacturing, however, since they are conditioned on a fixed size of labor wedges. To the extent that the distortions themselves are partially explained by domestic policy it is likely that reforming those domestic policies should be preferred to taking the roundabout way of undoing the effects of distortions via trade policy. Even if reducing sectoral wage differentials directly is not feasible, there might still be other policy instruments (such as production taxes and subsidies) available that are preferable to tariffs.[42]

Intersectoral Labor Distortions

I now turn to a set of counterfactuals looking at the interactions between intersectoral labor distortions and international trade from a different perspective. Instead of asking how the presence of distortions affects the benefits from trade, we can also study a complementary issue of how international trade affects the benefits of reducing domestic distortions. The answer that emerges from the analysis below is that trade tends to magnify the impact of distortions.

The first counterfactual involves reducing the calibrated wedges simultaneously in all countries. Suppose hypothetical institutional and policy reforms succeeded in eliminating half of distortions in each country, which I model by setting $\xi'_{Kj} = (\xi_{Kj} + 1)/2$ for $K \in \{A, S\}$ and for all j. Table 9 reports the average welfare gain from this hypothetical change by quartile of aggregate productivity in the reference year. The benefits are strongly declining in income: whereas welfare of households in the least developed countries rises on average by an impressive 18.3%, the gain for the richest group is a trivial 0.2%. Since proportional reductions in distortions mean bigger absolute change for bigger wedges, the ranking of gains should not be surprising in light of the pattern of distortions declining in income documented in Section 4.2.

To illustrate the importance international trade plays in enabling large gains for developing countries the next exercise considers the same reduction of labor wedges but undertaken in a closed economy. More precisely, starting in a counterfactual closed economy equilibrium with the same wedges as in the benchmark calibration I ask what would happen if we halved the distortions. In that case (all results in Table 9) the consequences for welfare are minimal for all countries, with average gain between 0.1% for the richest quartile and 0.3% for the first quartile.

Why are the benefits for poor countries so much smaller in autarky? The main effect of lowering distortions in a closed economy is the change in relative prices of sectoral outputs following from the change in relative labor costs. However, consumer's preferences in the calibrated model allow little substutitability in consumption across sectors as was emphasized in discussing the elasticities in Table 1. Since changes in relative prices induce only minor adjustment in consumption patterns the labor allocation also changes little in the closed economy. With neither consumption nor production

[42] The theoretical validity of that point in a simpler model was shown in an important paper by Bhagwati and Ramaswami (1963).

adjusting much in response to lowering labor distortions the welfare effects of that experiment are very modest. In contrast, with international trade an increase in the agricultural wage relative to manufacturing wage leads to the substitution of imports for domestic production in agriculture and associated outflow of labor from the least productive agricultural sector. Table 9 reports that the share of workers in agriculture in the first quartile falls in response to the hypothetical wedge reduction by 17.7 p.p. with trade but remains virtually unchanged in autarky. Thus despite still limited changes in consumption patterns poor countries can realize substantial gains due to the reallocation of production across sectors.

So far I have considered reducing both distortions by the same factor. We can also study the effects of mitigating only one distortion even though such an experiment could actually increase the distortion measured as deviation of w_{Aj}/w_{Sj} from unity in some cases. Nevertheless, the results of counterfactuals halving one distortion at a time (still Table 9) reveal that it is the distortion between the tradable sectors that matters quantitatively. Reducing the wedge between manufacturing and services by itself yields average welfare gain of less than 0.2% for all income groups.

The counterfactuals described above involve simultaneous proportional reduction in distortions in all countries. What happens if only one country mitigates its domestic distortions? Contrasting the two scenarios is a useful way to illustrate the global consequences of actions taken at a country level. To give a concrete example, India gains 3.3% in welfare terms if it reduces its distortions by half along with other countries. If it is the only country halving distortions then its welfare rises by a much higher 13.9%. The larger gain reflects more labor reallocation taking place in the unilateral experiment: the share of labor in agriculture in India falls from 0.64 to 0.61 if there is a global reduction in distortions and to 0.49 if reduction occurs in India only. Large gains for India come at a cost of welfare losses in other countries, however. In fact, all other countries except Hungary lose from India's unilateral reduction, with losses in 8 countries larger than 1% of welfare. The identity of the biggest losers, and the underlying logic behind their losses is the same as in the discussion of India unilaterally imposing a manufacturing tariff. In both cases agricultural production shifts from India to (mostly) neighboring countries which lose from the movement of labor into their relatively unproductive sector. These examples thus also illustrate international complementarity of domestic policies: reducing distortions (or sheltering manufacturing with tariffs) becomes relatively more important if other countries (and your major trading partners in particular) reduce their own distortions (or increase protection of their industrial sectors).

An interesting question concerns the optimal size of distortions. Implicit in the discussion is the notion that equalizing sectoral wages is optimal. Strictly speaking, it is only true in the closed economy where there is no reason to distort the allocation of labor. The trading equilibrium is in the realm of second-best world, however, due to transport costs and distortions in other countries. Thus if the size of domestic wedges is partially determined by policy (recall the tax interpretation of wedges) than a country might actually be better off with some amount of distortions. The calculations for a few countries suggest that it might indeed be optimal to distort domestic labor allocation, however the magnitude of optimal distortions is small relative to the calibrated wedges and the welfare benefit of such distortionary policy over eliminating wedges is tiny.

5.2 Time-Series Results

In this subsection I shift the focus to the time-series dimension. The counterfactual simulations are intended to gauge the importance of international trade and changes in intersectoral distortions for the process of structural transformation. In interpreting those results one should keep in mind the caveat that my setup is essentially static and hence does not take into account possible cumulative forces. For example, in comparing hypothetical paths for a given country for different levels of distortions I do not take into account the fact that higher output in one period could affect future labor productivity through factor accumulation. It is therefore likely that by abstracting from indirect effects I understate the long-run importance of trade and distortions for shaping the composition of sectoral activity.

Trade and Structural Transformation

Globalization is often blamed in the popular press for destroying the well-payed manufacturing jobs in developed countries. The framework developed in this study lets us assess the validity of that sentiment. Figure 9 plots labor shares in the US and in Japan between 1970-2005 under three scenarios: (i) for the baseline calibration, which matches the measured data; (ii) in the counterfactual simulation with aggregate trade deficits eliminated; and (iii) in hypothetical economies that were closed to trade over that period but were otherwise identical. As Figure 9 illustrates, the decline in U.S. manufacturing employment would have indeed be slower if U.S. remained in autarky. However, the faster decline can be attributed to the widening of U.S. trade deficit towards the end of the sample rather than trade per se: the fall of manufacturing employment would be essentially the same in autarky and if the U.S. trade was balanced. Over longer horizons the decline is driven primarily by patterns of sectoral labor productivity growth and income effects which trade cannot counteract. To make this point stronger, the second panel of Figure 9 presents analogous graphs for Japan. It is a polar case to the US in that it had persistent trade surpluses, which translate to higher manufacturing employment shares than in autarky or in balanced trade scenario in any given year. But in Japan the secular decline of industrial employment is inevitable as well as it is also driven by relatively fast productivity growth in that sector and overall income growth.

To illustrate the effects of openness to trade on structural transformation for a broad range of countries I compare the average annual change in sectoral labor shares under autarky and under the balanced-trade scenario. Figure 10 plots the results of that calculation. With trade the movement out of agriculture and towards services is a little faster on average. But the small magnitude of that effect shows that in the framework of this paper openness to trade by itself does not contribute to the process of structural transformation in a major way. This suggests that in accounting for structural change patterns across countries the trade channel emphasized in theoretical work of Yi and Zhang (2010) might not be empirically of first order importance.

Wedges and Structural Transformation

Similarly as for trade, we can inquire about the importance of intersectoral distortions for structural transformation. By analogy with openness we could compare changes in labor shares in the baseline calibration with a counterfactual scenario in which wedges are held at some constant level. However, in this case we can do better since the calibration provides us with wedges that give a natural metric for the size of distortions. The precise question I answer below is therefore: does the process of reallocation of labor across sectors proceed faster in countries in which distortions get smaller over time? The average annual decline in agricultural labor share and increase in services labor share can be thought of as a measure of the speed of structural transformation in that exercise.

As a starting point we could compute the correlation between changes in wedges and changes in labor shares in the baseline calibration. Since in most countries $\xi_A < 1$, an increase in agricultural wedge ($\Delta\xi_A > 0$) means that the distortions get smaller over time ($\Delta\zeta_A < 0$). The first panel of Table 10 shows a statistically significant positive correlation between $\Delta\zeta_A$ and $\overline{\Delta l_A}$ and a statistically significant negative correlation between $\Delta\zeta_A$ and $\overline{\Delta l_S}$ (column 3). This means that falling agricultural distortions are indeed associated with faster movement out of agriculture and movement towards services. Changes in the magnitude of the wedge in services, in contrast, are not systematically related to the speed of structural transformation (column 4).

Of course, it could be the case that structural transformation proceeds faster in countries with falling agricultural distortions for unrelated reasons, for instance because those countries also have faster growth of productivity in agriculture. We can give the correlations a more casual interpretation by using the model-generated counterfactual data to "control" for time-varying factors other than wedges. Specifically, I compute $\overline{\Delta l_{Ki}^{cf}}$, the average annual changes in labor share of sector K in a counterfactual equilibrium in which wedges in country i are held constant at the level of their geometric average over the sample period. Then $\Delta\overline{\Delta l_{Ki}} = \overline{\Delta l_{Ki}} - \overline{\Delta l_{Ki}^{cf}}$, the difference in average change in labor share in the baseline calibration and in the counterfactual, can in principle be attributed to the change in wedges in country i over time only, since all other factors such as technology growth, changes in trade costs or changes in wedges in other countries are the same in baseline and in the counterfactual. The second panel of Table 10 shows the correlations between $\Delta\overline{\Delta l_{Ki}}$ and changes in wedges. The positive relationship between falling distortions in agriculture and speed of structural transformation is preserved if we control for other factors. That point is also illustrated graphically in Figures 11 and 12, which plot $\overline{\Delta l_{Ai}}$ and $\Delta\overline{\Delta l_{Ai}}$ against $\Delta\xi_{Ai}$, respectively. In both figures the negative slope is statistically significant.

6 Conclusions

The primary goal of this paper is to quantify the impact of domestic distortions on the welfare gains from international trade. To address this issue, I build a model of trade in which wedges between labor costs faced by producers in different sectors distort the intersectoral allocation of labor.

I apply the model to the data for a diverse set countries over the period spanning three decades. In order to account for sectoral composition of economic activity in a sample with a broad range of incomes, I introduce a new parametrization of nonhomothetic preferences. To calibrate the key parameters of these preferences, I develop a novel methodology that exploits the ability of the model to match the central features of the process of structural change.

My main result is that domestic intersectoral distortions affect the welfare gains from trade in a quantitatively important way. To isolate the effect of domestic frictions, I derive a theoretical relationship between the gains from trade that models with and without distortions would predict given the same data. Standard models that abstract from intersectoral distortions would overstate the benefits of trade for countries that are net exporters in sectors in which distortions depress the value marginal product of labor. Intuitively, in such countries international trade magnifies the misallocation of labor caused by domestic distortions. Empirically, I find that the marginal product of labor is almost universally lower in agriculture than in manufacturing. The workhorse trade models therefore overpredict the gains from trade for large agricultural net exporters while understating the gains from trade for countries specializing in manufacturing exports. For example, the gains from trade in my model are 6.4 p.p. lower for the Philippines and 3.4 p.p. higher for Japan in 1995 than in a frictionless framework.

Beyond improving the measurement of the gains from trade, my results show two additional benefits of incorporating intersectoral distortions into a trade model. First, it generates new insights into trade policy. I find the reduced-form evidence that trade policy in developing countries exhibits a pro-manufacturing bias. My quantitative model can rationalize this pattern since it predicts that poor countries have particularly strong incentives to unilaterally protect their manufacturing sector. Second, my results suggest that taking into account openness to trade is important for assessing the welfare costs of domestic distortions. I find that a hypothetical reduction in distortions generates much larger welfare gains in poor countries when international trade can decouple domestic consumption and production patterns.

To provide quantitative evidence on domestic distortions and the gains from trade, the model inevitably makes a number of assumptions which could be relaxed in further work. In particular, in this paper I treat intersectoral distortions as fixed and independent of the trade regime. In future research it would be interesting to distinguish between different types of distortions and relate them to actual policies and institutions. This would open up an interesting possibility that the magnitudes of domestic frictions and international trade flows are jointly determined.

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Tables

Table 1: Calibrated Preference Parameters

Parameter	α_A	α_M	α_S	$\overline{c}_A$
Value	-1.00	-0.89	-0.68	3.90×10^{-3}

Implied mean elasticities			
Income elasticity	η_A	η_M	η_S
	0.30	0.91	1.14
Own-price elasticity	ϵ_{AA}	ϵ_{MM}	ϵ_{SS}
	-0.02	-0.34	-0.81
Elast. of substitution	σ_{AM}	σ_{AS}	σ_{MS}
	-0.06	0.02	0.19

Notes: Income elasticity: $\eta_K = \frac{\partial \log x_K(p,m)}{\partial \log m}$; Own-price elasticity: $\epsilon_{KK} = \frac{\partial \log x_K(p,m)}{\partial \log p_K}$; Allen-Uzawa elasticity of substitution: $\sigma_{ij} = \frac{1}{e_j}\frac{\partial \log h_i(p,U)}{\partial \log p_j}$, where $x_K(p,m)$ is Marshallian demand and $h_K(p,U)$ is Hicksian demand for sector K and e_K is the expenditure share of sector K. Table reports mean elasticities across countries computed for 1995.

Table 2: Wedges in Cross-Section and in Time-Series

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Dependent variable:	ξ_A	ξ_S	ζ_A	ζ_S	ξ_A	ξ_S	ζ_A	ζ_S
Log GDP per worker	0.121	0.031	-0.118	-0.063				
	(0.000)	(0.440)	(0.000)	(0.014)				
year					-.0046	-.0065	.0039	0.0021
					(0.004)	(0.002)	(0.005)	(0.217)
country FE					yes	yes	yes	yes
year FE	yes	yes	yes	yes				

Notes: $p-$values in parentheses. Standard errors are clustered at the country level. GDP per worker calculated as real GDP from PWT 7.0 ($rgdpch \times POP$) divided by total employment L_i, expressed in thousand dollars per worker.

Table 3: Comparative Advantage and Aggregate Productivity

	(1)	(2)
Dependent. variable:	$\frac{T_{Ai}^{1/\theta_A}}{T_{Mi}^{1/\theta_M}}$	$\frac{T_{Ai}^{1/\theta_A} c_{Ai}^{-1}}{T_{Mi}^{1/\theta_A} c_{Mi}^{-1}}$
Log GDP per worker	0.113	0.028
	(0.000)	(0.578)
year FE	yes	yes

Notes: $p-$values in parentheses. Standard errors are clustered at the country level. GDP per worker calculated as real GDP from PWT 7.0 ($rgdpch \times POP$) divided by total employment L_i, expressed in thousand dollars per worker.

Table 4: Variance Decomposition of Relative Competitiveness

Share of $Var\left(\log \frac{T_{Ai}^{1/\theta_A} c_{Ai}^{-1}}{T_{Mi}^{1/\theta_A} c_{Mi}^{-1}}\right)$ explained by	
$Var\left(\log \frac{A_{Ai}}{A_{Mi}}\right)$	1.84
$Var\left(\log \frac{\pi_{Aii}^{1/\theta_A}}{\pi_{Mii}^{1/\theta_M}}\right)$	0.01
$Var\left(\log \xi_{Ai}^{-1}\right)$	0.97
$2Cov\left(\log \frac{A_{Ai}}{A_{Mi}}, \log \frac{\pi_{Aii}^{1/\theta_A}}{\pi_{Mii}^{1/\theta_M}}\right)$	-0.02
$2Cov\left(\log \frac{A_{Ai}}{A_{Mi}}, \log \xi_{Ai}^{-1}\right)$	-1.78
$2Cov\left(\log \frac{\pi_{Aii}^{1/\theta_A}}{\pi_{Mii}^{1/\theta_M}}, \log \xi_{Ai}^{-1}\right)$	-0.01

Notes: Variance decomposition calculated using the entire sample with 1281 observations.

Table 5: Welfare Gains from Trade

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Country	GFT	Δl_A	Δl_M	Δl_S	δ_A^T	$\widetilde{GFT}$	Υ	$\widetilde{LFA}^{ND}$	GFT^{ND}
Argentina	-2.60	0.07	-0.04	-0.02	-3.53	-2.60	1.05	0.98	1.92
Australia	0.84	0.04	-0.04	0.00	-2.90	0.82	1.03	0.97	3.35
Austria	10.32	-0.02	-0.04	0.06	0.40	10.13	0.97	0.92	7.92
Bangladesh	4.07	-0.02	0.00	0.02	0.82	4.06	0.98	0.98	2.24
Belgium	24.89	-0.03	-0.14	0.17	0.26	23.25	1.01	0.76	25.55
Bolivia	-9.01	0.13	-0.08	-0.05	-5.89	-8.99	1.17	0.93	6.49
Brazil	-1.21	0.02	-0.01	-0.01	-0.91	-1.21	1.03	0.99	1.36
Canada	5.99	0.01	-0.05	0.04	-0.57	5.75	1.02	0.92	8.18
Chile	-0.49	0.07	-0.06	-0.01	-4.02	-0.51	1.07	0.94	5.79
China	3.74	-0.01	0.00	0.01	0.27	3.74	0.99	0.97	2.92
Colombia	-1.86	0.06	-0.05	-0.02	-4.04	-1.86	1.05	0.97	3.33
Czech Rep.	11.46	0.00	-0.06	0.06	0.04	11.29	0.99	0.89	10.66
Denmark	6.79	0.03	-0.08	0.05	-2.48	6.60	1.01	0.93	7.38
Finland	5.64	-0.02	-0.02	0.04	0.79	5.52	1.00	0.95	5.50
France	4.55	0.00	-0.03	0.03	-0.04	4.46	1.00	0.96	4.51
Germany	5.96	-0.03	-0.02	0.04	0.79	5.88	0.98	0.96	4.47
Greece	1.78	0.08	-0.08	0.01	-4.23	1.76	1.03	0.96	4.15
Hungary	11.78	0.03	-0.10	0.07	-2.26	11.54	0.99	0.90	10.41
India	-0.05	0.01	-0.01	0.00	-0.70	-0.05	1.02	0.98	1.53
Indonesia	3.13	0.00	-0.01	0.01	-0.19	3.11	1.01	0.96	4.31
Ireland	12.24	-0.02	-0.07	0.09	1.07	11.51	1.04	0.85	15.51
Italy	4.97	-0.03	-0.01	0.03	1.16	4.91	0.99	0.97	3.54
Japan	4.77	-0.04	0.01	0.04	1.00	4.75	0.97	0.99	1.33
Korea	6.55	-0.03	-0.01	0.04	1.30	6.48	0.99	0.95	5.23
Malaysia	16.35	0.06	-0.14	0.08	-4.40	16.06	1.07	0.79	21.54
Mexico	6.91	-0.01	-0.03	0.04	0.08	6.81	0.99	0.94	5.95
Netherlands	11.53	0.01	-0.09	0.08	-1.45	10.77	1.04	0.86	14.73
Norway	3.07	0.01	-0.03	0.02	-0.76	2.96	1.03	0.94	5.93
Pakistan	4.46	-0.03	0.00	0.02	1.13	4.44	0.98	0.98	2.35
Peru	2.96	0.00	-0.01	0.01	-0.14	2.94	1.00	0.97	2.98
Philippines	2.34	0.03	-0.04	0.00	-2.01	2.33	1.07	0.91	8.73
Poland	5.29	0.00	-0.02	0.03	0.12	5.26	0.99	0.96	4.35
Portugal	12.11	-0.04	-0.02	0.06	1.41	11.93	0.96	0.92	7.77
Slovakia	21.83	-0.03	-0.11	0.13	1.56	21.03	0.97	0.81	19.80
Spain	3.57	0.01	-0.03	0.02	-0.78	3.53	1.01	0.96	4.07
Sri Lanka	6.92	0.00	-0.04	0.03	-0.54	6.84	0.99	0.94	6.13
Sweden	6.41	-0.02	-0.03	0.05	0.98	6.22	1.00	0.94	6.53
Switzerland	8.42	-0.02	-0.04	0.06	0.89	8.20	0.99	0.93	7.39
Taiwan	11.61	-0.04	-0.04	0.07	0.83	11.37	0.97	0.91	9.11
Thailand	-21.83	0.19	-0.09	-0.09	-5.13	-21.66	1.33	0.92	8.20
UK	4.32	-0.01	-0.02	0.03	0.33	4.25	1.01	0.95	5.22
US	1.26	0.01	-0.01	0.01	-0.45	1.25	1.01	0.98	1.84
Venezuela	6.18	-0.05	0.00	0.05	1.51	6.13	0.98	0.96	3.95
Viet Nam	-19.63	0.14	-0.08	-0.06	-5.99	-19.71	1.29	0.93	7.01

Notes: GFT and GFT^{ND} are welfare gains from trade expressed in percentage terms in a model with and without distortions. Δl_K denotes change in labor share in sector K moving from autarky to trade equilibrium in a model with distortions. δ_A^T is the trade deficit in agriculture relative to GDP, expressed in percentage terms. $\widetilde{GFT} = 100\left(1 - \Upsilon \widetilde{LFA}^{ND}\right)$ gives the approximation to GFT, where Υ is the labor reallocation channel and $\widetilde{LFA}^{ND}$ denotes losses from moving to autarky in a CES model without distortions. All numbers are for year 1995.

Table 6: Gains from Trade for Alternative Wedges

	(1)	(2)	(3)	(4)	(5)
Weight χ:	1.00	0.75	0.50	0.25	0.00
Bolivia	-9.01	-0.73	2.78	4.94	6.49
China	3.74	2.97	2.86	2.87	2.92
France	4.55	4.54	4.52	4.52	4.51
India	-0.05	0.86	1.25	1.44	1.53
Japan	4.77	2.83	2.04	1.61	1.33
US	1.26	1.43	1.58	1.71	1.84
Mean	4.73	5.89	6.33	6.62	6.84

Notes: Welfare gains from trade calculated under the assumption that true wedges are given by $\xi_{Kj} = \chi\xi^0_{Kj} + (1-\chi)$, where ξ^0_{Kj} is the baseline wedge used in the paper. Mean corresponds to a simple mean across 44 countries in the sample in 1995.

Table 7: Optimal Tariffs for Selected Countries

	Tariff in agr. [%]	Tariff in man. [%]	Welfare gain [%]
China	-60	75	27.20
India	-40	75	7.39
Portugal	-30	30	3.96
USA	-10	30	0.51
Mean	-20.91	64.66	6.18

Notes: Welfare gains from unilaterally imposing optimal tariffs or subsidies in agriculture and manufacturing. The choice of tariffs/subsidies was restricted to lie on a grid which explains round numbers for optimal policy choices. Grid for agricultural tariffs [%]: (-80,-70,-60,-50,-40,-30,-20,-10,0,10,20,50,100,400); grid for manufacturing tariffs [%]: (-80,-50,-20,-10,0,10,20,30,40,50,75,100,200,300,400,600,900). The starting point is an equilibrium with aggregate trade deficits eliminated in 1995. Mean corresponds to a simple mean across 44 countries in the sample in 1995.

Table 8: Relative Trade Protection

Dependent variable: RRA	(1)	(2)
Log GDP per worker	0.400	0.599
	(0.000)	(0.013)
country FE		yes
year FE	yes	yes

Notes: $p-$values in parentheses. Standard errors are clustered at the country level. GDP per worker calculated as real GDP from PWT 7.0 ($rgdpch \times POP$) divided by total employment L_i, expressed in thousand dollars per worker. RRA is relative rate of assistance (agriculture relative to nonagriculture) from DAI database. Regression on pooled sample with 1089 observations.

Table 9: Reducing Intersectoral Labor Distortions

Income quartile	1st	2nd	3rd	4th
Reducing distortions by half				
Welfare gain	18.27	3.64	1.30	0.19
Δl_A	-17.67	0.60	-0.60	2.18
Δl_M	10.17	-2.70	-0.20	-2.05
Δl_S	7.50	2.10	0.80	-0.13
Reducing distortions by half in a closed economy				
Welfare gain	0.27	0.18	0.11	0.09
Δl_A	-0.01	0.00	-0.03	0.00
Δl_M	0.28	0.18	0.01	0.24
Δl_S	-0.27	-0.18	0.01	-0.25
Reducing ζ_A by half				
Welfare gain	17.88	3.46	1.19	0.14
Reducing ζ_S by half				
Welfare gain	0.11	0.14	0.12	0.06

Notes: Welfare gains in terms of equivalent variation as a percentage of expenditure in the original equilibrium. Δl_K denotes change in labor share (in percentage points) in sector K moving to equilibrium with lower distortions. Magnitude of distortion measured as $\zeta_K = |\xi_K - 1|$. For each quartile the means of respective variables are reported. All numbers are for year 1995.

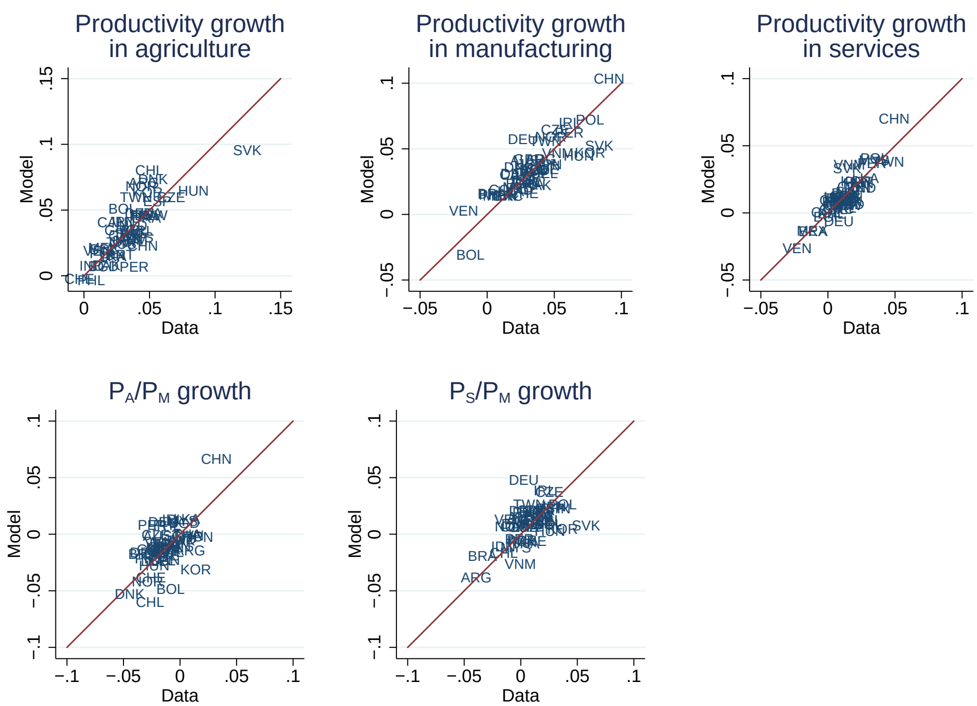
Table 10: Correlation Between Changes in Wedges and Changes in Labor Shares

	(1) $\Delta\xi_{Ai}$	(2) $\Delta\xi_{Si}$	(3) $\Delta\zeta_{Ai}$	(4) $\Delta\zeta_{Si}$
Baseline				
$\overline{\Delta l_A}$	-0.49	-0.08	0.49	0.13
	(0.00)	(0.62)	(0.00)	(0.39)
$\overline{\Delta l_M}$	0.41	0.05	-0.39	-0.10
	(0.01)	(0.77)	(0.01)	(0.50)
$\overline{\Delta l_S}$	0.36	0.08	-0.38	-0.10
	(0.02)	(0.62)	(0.01)	(0.49)
Relative to constant wedge counterfactual				
$\Delta\overline{\Delta l_A}$	-0.49	-0.49	0.53	0.08
	(0.00)	(0.00)	(0.00)	(0.60)
$\Delta\overline{\Delta l_M}$	0.61	0.53	-0.65	-0.17
	(0.00)	(0.00)	(0.00)	(0.26)
$\Delta\overline{\Delta l_S}$	0.33	0.40	-0.37	0.01
	(0.03)	(0.01)	(0.01)	(0.94)

Notes: $\overline{\Delta l_K}$ denotes the average annual change in labor share (expressed in percentage points per year) in sector K between the last year and the first year country is in the sample. $\Delta\overline{\Delta l_K}$ gives the difference between $\overline{\Delta l_K}$ in the baseline calibration (which is the same as data) and between $\overline{\Delta l_K}$ from the counterfactual simulation that keeps wedges in a country at a constant level equal to the geometric mean of wedges in baseline. The numbers in parentheses are $p-$values of the correlation coefficients. $\zeta_K = |\xi_K - 1|$ measures the absolute magnitude of distortions.

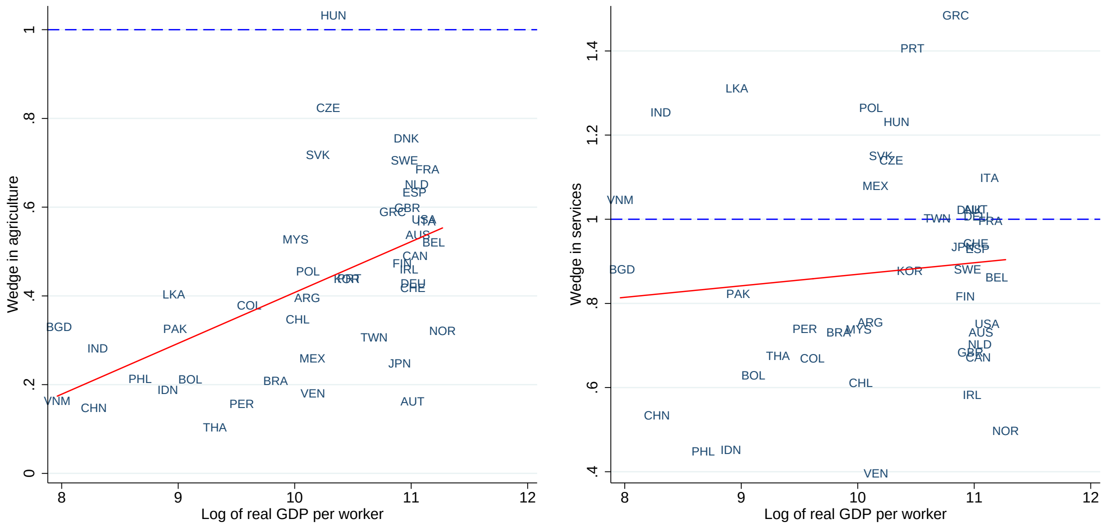
Figures

Figure 1: Changes in Sectoral Productivities and Relative Prices



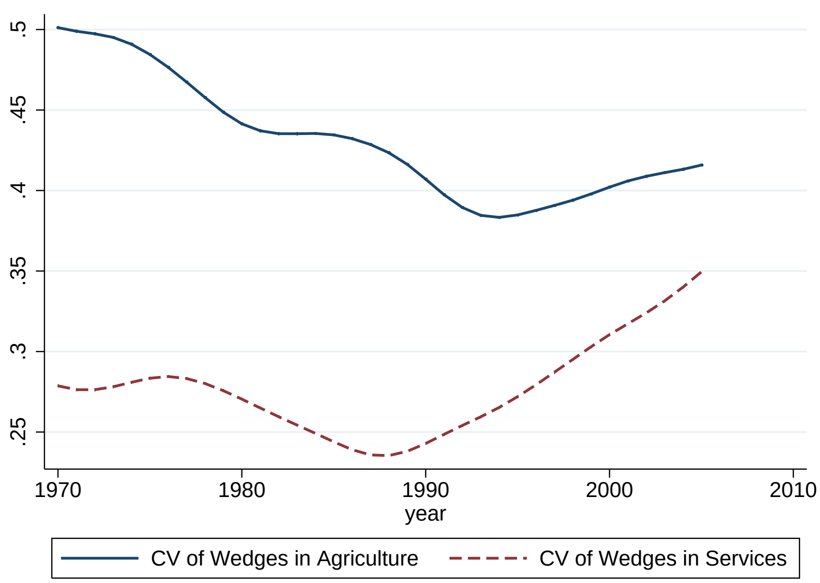
Notes: Annualized average log growth rates of quantity z for country i computed as $\frac{1}{t_l^i - t_f^i} \log\left(z_{it_l^i}/z_{it_f^i}\right)$, where t_l^i and t_f^i is the last and first year that country i appears in the sample.

Figure 2: Wedges in 1995



Notes: Red solid lines present the best linear fit between the wedge and the logarithm of aggregate productivity.

Figure 3: Dispersion of Wedges over Time

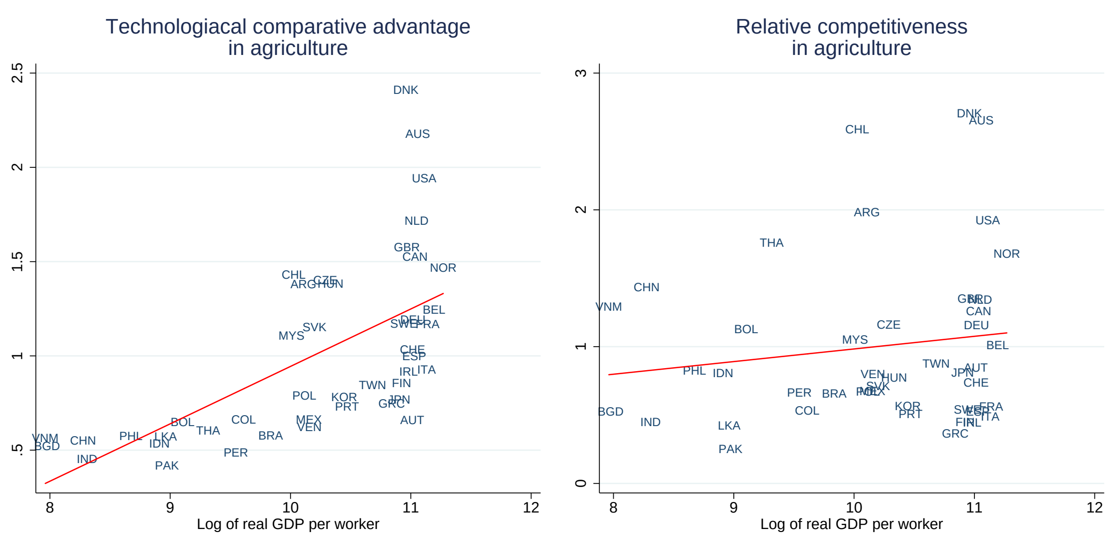


Notes: Coefficient of variation of ξ_A and ξ_S over time in the subsample of 21 countries present in the sample throughout 1970-2005.

Figure 4: Relative Sectoral and Aggregate Labor Productivity

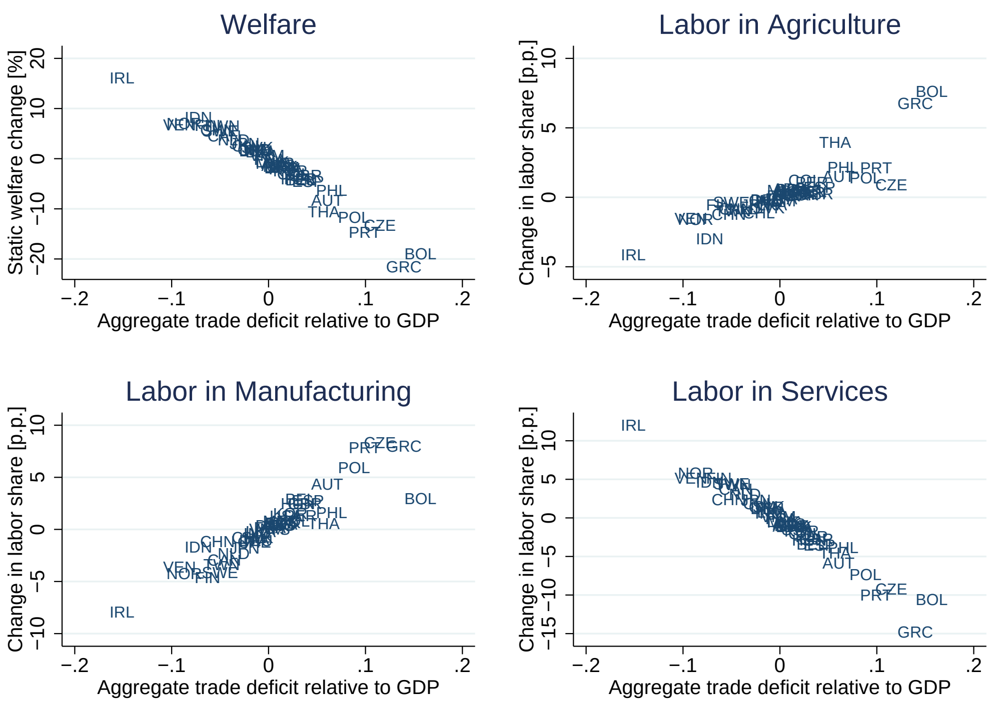
Notes: For each of the first three quartiles of real GDP per worker the figure shows mean labor productivity (in each sector and aggregate) relative to the corresponding mean for the fourth quartile.

Figure 5: Measures of Comparative Advantage in 1995



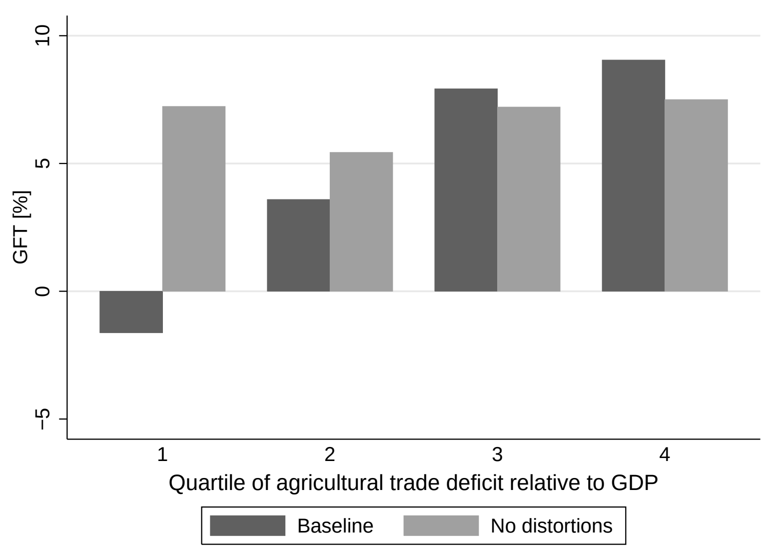
Notes: Technological comparative advantage and relative competitiveness in agriculture computed using formulas (29) and (30) in the main text, respectively. Red solid lines present the best linear fit between the measure of comparative advantage in agriculture and the logarithm of aggregate productivity.

Figure 6: Changes in Welfare and Labor Shares due to Eliminating Aggregate Trade Deficits



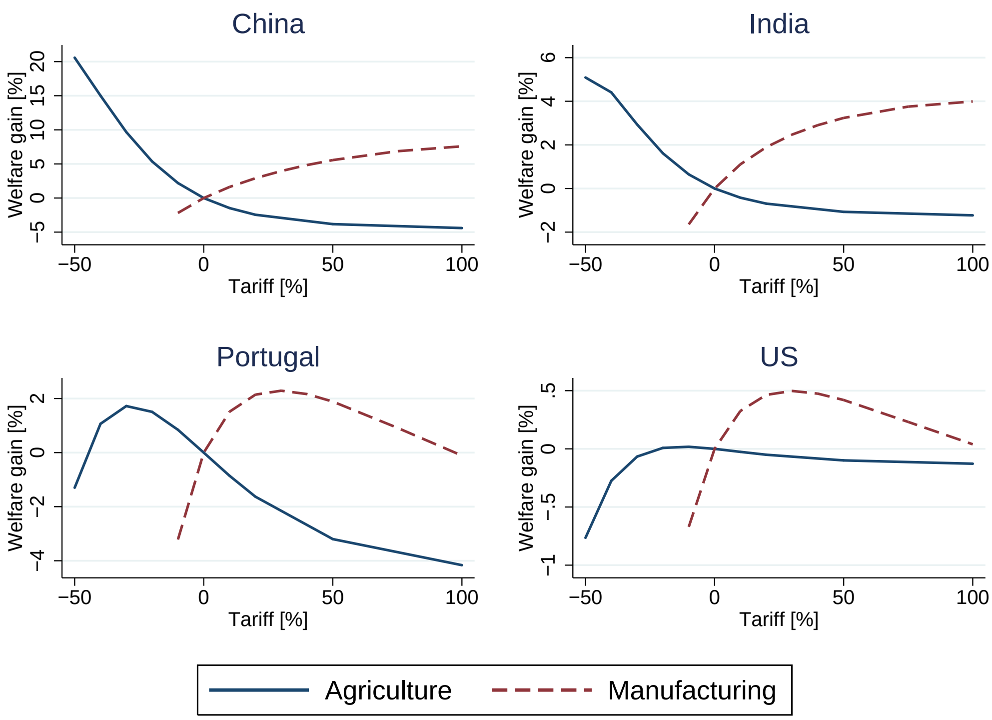
Notes: Figure shows the effects of moving from baseline equilibrium to equilibrium with balanced aggregate trade in 1995.

Figure 7: Welfare Gains from Trade in 1995



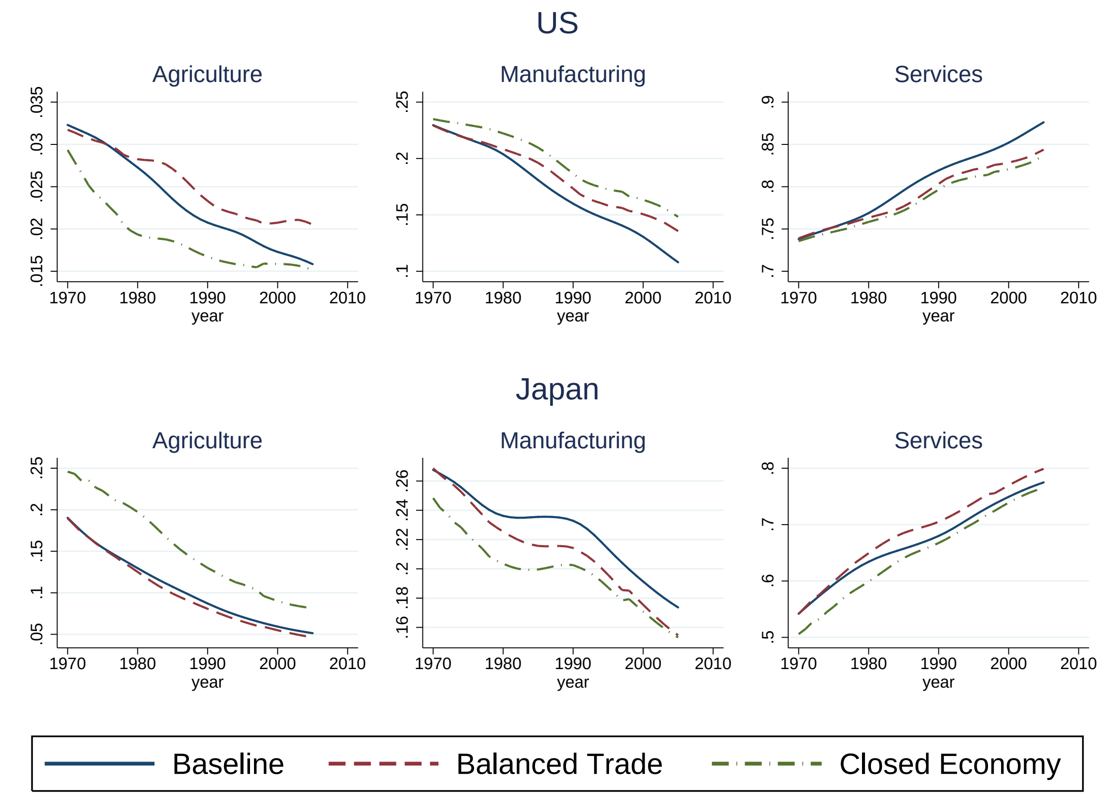
Notes: Welfare gains from trade in the baseline model with intersectoral distortions and in a model ignoring distortions.

Figure 8: Welfare Gains From Unilaterally Imposing Tariffs



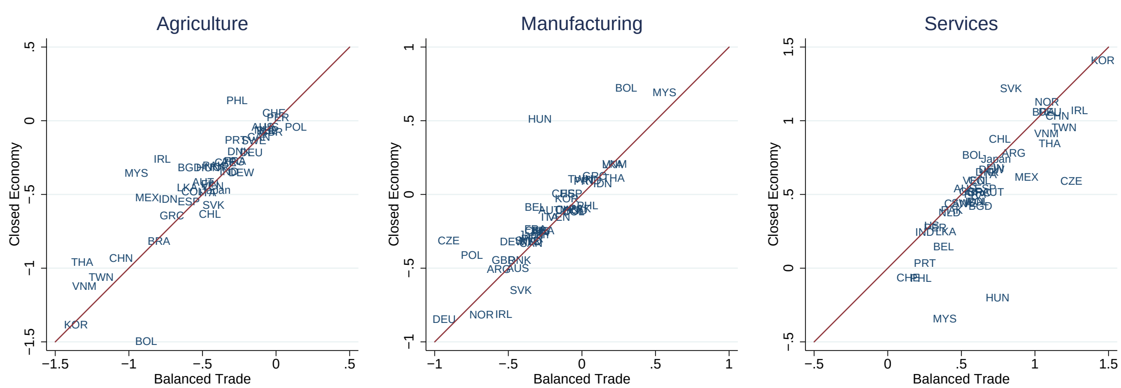
Notes: Welfare gains from unilaterally imposing a tariff/subsidy in agriculture or manufacturing while the tariff in the other sector is zero. The starting point is an equilibrium with aggregate trade deficits eliminated in 1995.

Figure 9: Trade and Labor Shares



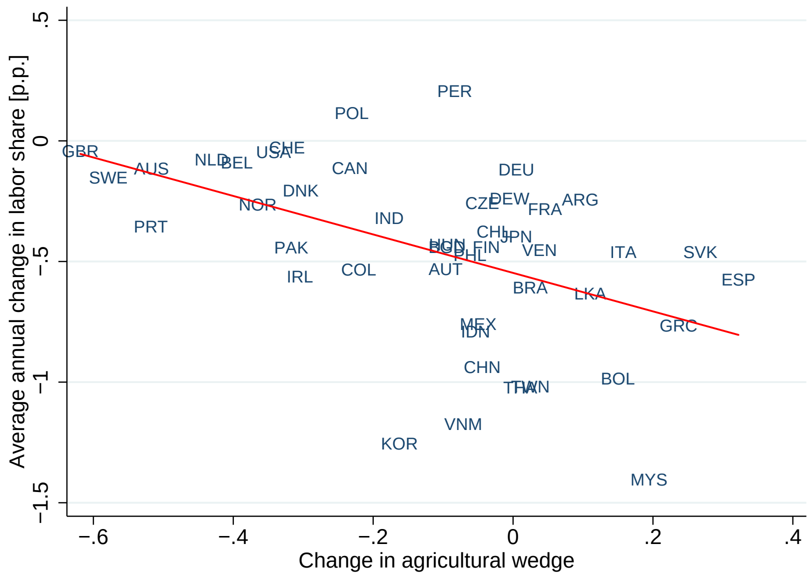
Notes: Sectoral labor shares in the baseline case (matching the data) and in two counterfactual scenarios: imposing balanced trade or autarky in every year.

Figure 10: Trade and Changes in Labor Shares



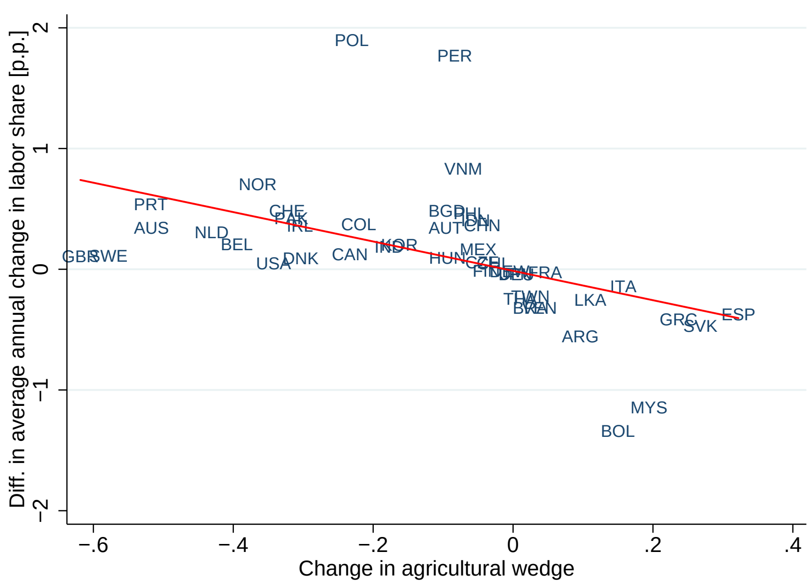
Notes: Graphs show the average annual change in sector's labor share (expressed in percentage points per year) between the last year and the first year country is in the sample in two counterfactuals.

Figure 11: Changes in Wedges and Changes in Agricultural Labor Shares



Notes: Figure plots the average annual change in sector's labor share (expressed in percentage points per year) against change in agricultural wedge between the last year and the first year country is in the sample.

Figure 12: Changes in Wedges and Changes in Agricultural Labor Shares Controlling for Other Factors



Notes: Figure plots the difference between the average annual change in sector's labor share (expressed in percentage points per year) in the baseline and in the counterfactual keeping wedges constant against change in agricultural wedge between the last year and the first year country is in the sample.

A Data Appendix

A.1 Aggregate Data

I calculate the PPP-adjusted GDP as a product of real GDP per capita ($rgdpch$) and population (POP) taken from version 7.0 of the Penn World Table (Heston et al. (2011)). I HP-filter the resulting series with smoothing parameter 25 (falling in the 6.25-100 range standard in the literature for annual data) and divide by HP-filtered employment (see below) to obtain the smoothed real GDP per worker. PWT 7.0 is also used as a source for the level of nominal exchange rate ($XRAT$).

A.2 Sectoral Output, Employment and Price Data

To conduct the analysis of structural transformation at a sectoral level I construct an unbalanced panel of between 26 and 44 countries over the period 1970-2005. I assemble data from four sources: EU KLEMS database [O'Mahony and Timmer (2009)], GGDC 10-sector database [Timmer and de Vries (2009)], OECD STAN database [OECD (2011)] and Asian Productivity Organization database [APO (2010)]. Table 11 presents the sample coverage and the primary source of information for each country. These sources provide information at a higher level of disaggregation than used in this study. I therefore aggregate the data by constructing a three sector classification: agriculture (comprising ISIC Rev. 3 sectors 01-05: agriculture, hunting, forestry and fishing), tradable industry (comprising ISIC sectors 10-37: mining and quarrying and manufacturing industries) and nontradables (comprising all other activities). In the paper I refer to those sectors as agriculture, manufacturing and services. To eliminate the effects of cyclical fluctuation, which are beyond the scope of this paper, I smooth the time-series of interest using the Hodrick-Prescott filter with smoothing parameter 25. The following paragraphs present more detailed description of construction of individual variables.

The measure of sectoral employment I use is Total Employment (Number of Persons Engaged). This broad concept of labor input is the only measure consistently available for a large set of countries in all four databases. To obtain the smoothed series I simply filter the time series with sectoral employment separately for each sector and country.

To construct the sectoral value added in U.S. dollars I proceed in several steps. I begin by summing up all sectoral VA in current local prices to calculate the nominal GDP and apply the nominal exchange rate to obtain the GDP in U.S. dollars. Then I HP-filter the resulting series. Next I use the raw sectoral VA numbers to compute the VA shares and smooth those shares with HP-filter. The smoothed sectoral VA in U.S. dollars is then computed by applying the smoothed VA series to the smoothed GDP series. This calculation guarantees that aggregating smoothed VA across sectors yields the smoothed GDP. I find that this procedure is more robust than smoothing individual sectoral series separately as it filters the annual-frequency movements in nominal exchange rate in a consistent way across all sectors.

Calculations of labor productivity require data on VA in constant (or chained) prices to compute the quantity index of sectoral VA. I thus begin by using the price deflators for VA to convert the raw nominal VA for disaggregated industries to VA in constant prices. Summing across industries within a sector yields VA in constant prices at a sector level. To smooth the series I proceed similarly as for nominal VA - I first smooth separately the GDP in constant prices and sectoral shares of that GDP and then combine the smoothed GDP with smoothed shares to obtain smoothed constant-price VA levels for agriculture, manufacturing and services. Finally, I divide the smoothed constant-price VA series by the smoothed employment series to obtain series of quantity of VA per worker in each

Table 11: Sample Coverage

Country	Coverage Period	Primary Source
Argentina	1991-2005	GGDC 10-sector
Australia	1970-2005	EU KLEMS
Austria	1970-2005	EU KLEMS
Bangladesh	1985-2004	APO
Belgium	1970-2005	EU KLEMS
Bolivia	1986-2003	GGDC 10-sector
Brazil	1995-2005	GGDC 10-sector
Canada	1970-2005	STAN
Chile	1979-2005	GGDC 10-sector
China	1978-2005	APO
Colombia	1970-2005	GGDC 10-sector
Czech Republic	1995-2005	EU KLEMS
Denmark	1970-2005	EU KLEMS
Finland	1970-2005	EU KLEMS
France	1970-2005	EU KLEMS
Germany	1991-2005	EU KLEMS
West Germany	1970-1990	GGDC 10-sector
Greece	1970-2005	EU KLEMS
Hungary	1992-2005	EU KLEMS
India	1970-2004	GGDC 10-sector
Indonesia	1973-2005	GGDC 10-sector
Ireland	1970-1999	EU KLEMS
Italy	1970-2005	EU KLEMS
Japan	1970-2005	EU KLEMS
Korea	1973-2005	EU KLEMS
Malaysia	1975-1997	GGDC 10-sector
Mexico	1970-2005	GGDC 10-sector
Netherlands	1970-2005	EU KLEMS
Norway	1970-2005	STAN
Pakistan	1970-2005	APO
Peru	1991-2005	GGDC 10-sector
Philippines	1971-1997	GGDC 10-sector
Poland	1995-2005	EU KLEMS
Portugal	1970-2005	EU KLEMS
Slovakia	1995-2005	EU KLEMS
Spain	1970-2005	EU KLEMS
Sri Lanka	1971-2005	APO
Sweden	1970-2005	EU KLEMS
Switzerland	1991-2005	STAN
Taiwan	1970-1997	GGDC 10-sector
Thailand	1970-2005	GGDC 10-sector
United Kingdom	1970-2005	EU KLEMS
USA	1970-2005	EU KLEMS
Venezuela	1970-2003	GGDC 10-sector
Vietnam	1991-2005	APO

sector. I use those series, normalized to one in reference year 1995 in each sector and each country as the empirical measure of sectoral labor productivity growth.

To calculate the evolution of sectoral relative prices I start by calculating a smoothed price deflator for each sector by dividing smoothed sectoral VA in U.S. dollars by the quantity index of sectoral VA described in the previous paragraph. Next I divide the deflator for agriculture and services by the price deflator for manufacturing. Finally, I normalize the two indices to one in 1995 in each country.

For a couple of countries additional steps are required to calculate consistent time series over the relevant sample period. The data for Japan comes from GGDC 10-sector database for 1970-72 and from EU KLEMS for 1973-2005. To link the data from both sources I essentially combine the growth rates over 1970-73 from the GGDC 10-sector database with levels from EU KLEMS database in 1973 . The case of Germany is a little more complicated in that I use data for West Germany (from GGDC 10-sector database) for 1970-1990 and for unified Germany (from EU KLEMS) starting in 1991. To make the levels of variables comparable between the two entities when needed I exploit the fact that for 1991 data is available both for the unified Germany and the hypothetical West Germany.

A.3 International Trade Data

In order to compute bilateral trade flows in agriculture and manufacturing over the sample period I combine data from two datasets: the NBER-UN dataset [Feenstra et al. (2005)] and the BACI database prepared by researchers at CEPII [Gaulier and Zignago (2010)].

The NBER-UN dataset records bilateral trade flows at a 4-digit level according to SITC rev.2 classification. To map these disaggregated flows into two tradable sectors of the paper, agriculture and manufacturing, I develop a required concordance. As a starting point I use the SITC rev.2 5-digit to ISIC rev.2 4-digit concordance available from World Integrated Trade Solutions (WITS) project of the World Bank. On the production side I classify all industries with ISIC 4-digit code below 2000 as agriculture and the rest as tradable industry (called manufacturing in the paper). In the next step I adjust the mapping from trade classification to sector classification for a limited number of products which mostly involves moving some categories of meat, milled grains, and vegetable oils and their byproducts to agriculture. The rationale for this somewhat subjective adjustment is that industry classification is based on the final producer of a good with disregard of the share of value added in the last production stage. Since I use data on sectoral VA in my analysis I believe it is more appropriate if trade flows are assigned to sectors based on the VA content of the product and not the identity of the final processing industry. As measures of VA content at a product level are not readily available I had to use my judgment to conservatively reclassify some product categories. For example, WITS assigns both product 0113 ("Meat of swine, fresh, chilled or frozen") and product 0121 ("Bacon, ham & other dried, salted, smoked meat/ swine") to manufacturing industry 3111 ("Slaughtering, preparing and preserving meat"). I reclassify the first product as agriculture while keeping the processed meat assigned to manufacturing. Finally, in a very small number of cases I change the classification at 5-digit SITC level so that all SITC 4-digit code that appear in NBER-UN dataset can be unambiguously classified as agriculture or manufacturing.

The version of BACI dataset used in this paper provides bilateral trade flows by 6-digit HS92 product categories. To map these flows into agriculture and manufacturing in a way consistent with the treatment of NBER-UN data I first use the HS92 6-digit to SITC rev.2 5-digit concordance from

WITS and then assign the SITC products in the same way as for NBER-UN case.

Within the time span of the sample NBER-UN covers years between 1970-1995 while BACI data is available for 1995-2005. Since there are small differences in corresponding bilateral flows recorded by the two sources in overlapping years I compute a weighted average when both numbers are available.[43] In order to avoid discrete jumps in the data due to changing methodology, the weight on BACI flows is gradually increasing between 1995 and 2000.

The bilateral trade flows measured in U.S. dollars are then smoothed to reduce the effect of cyclical fluctuations and nominal exchange rate movements and thus to be more easily comparable with the data on smoothed VA in U.S. dollars described in the preceding subsection. Specifically, I apply the HP filter with smoothing parameter 25 separately to each available time series $\{X_{Kjit}\}$ of imports in industry K by country j from country i. Using the filtered series I then compute total imports by country j and total exports by country i as $IMP_{Kjt} = \sum_{i\neq j, i=1}^{N_t} X_{Kjit}$ and $EXP_{Kit} = \sum_{j\neq i, j=1}^{N_t} X_{Kjit}$. Because the country coverage varies by year also the the set of countries over which total imports and exports are calculated changes over time. This is necessary to make sure trade in the model world is balanced.

Finally, smoothed trade flows and smoothed VA in U.S. dollars VA_{Kj} are used to calculate bilateral trade shares as:

$$\pi_{Kji} = \frac{X_{Kji}}{VA_{Kj}\beta_K^{-1} + IMP_{Kj} - EXP_{Kj}},$$

where β_K is a median share of value added in gross output in the subsample of countries for which data on both value added and gross output is available (EU KLEMS subsample). Imports from home are computed as $X_{Kjj} = VA_{Kj}\beta_K^{-1} - EXP_{Kj}$ which ensures that the import shares sum to one for each country.

Trade flows and VA series, smoothed and expressed in U.S. dollars, are also used to compute the overall trade deficit of a country relative to its nominal GDP through the formula:

$$\delta_{jt} = \frac{IMP_{Ajt} - EXP_{Ajt} + IMP_{Mjt} - EXP_{Mjt}}{VA_{Aj} + VA_{Mj} + VA_{Sj}}.$$

In less than 3% of country-sector-year observation aggregate trade flows derived by following the procedures described above are too large relative to the scale of domestic industry to be consistent with the Eaton and Kortum structure. Those cases (Belgium, Netherlands, Denmark, Taiwan and Slovakia) are primarily small countries with high levels of reexports and processing trade that the model does not account for. To deal with most of those cases I use time trends of bilateral flows to extrapolate to the problematic years. In two particularly stark cases (agricultural trade of Belgium and the Netherlands) I go further and restrict bilateral trade flows in agriculture involving those countries in a way that stabilizes their trade/output ratio at a level compatible with the model.

B Calibration Details

In this Appendix I provide additional details of the algorithm used to calibrate the model.

[43]The two measures are very highly correlated with correlation coefficient above 0.99. R^2 from the regression of log NBER-UN flow on log BACI-flow is 0.97.

B.1 Calculating International Prices

Given sectoral wages, employment levels and prices in the reference year I find the model international prices through the following procedure. I first calculate the quantity of sectoral output as $q_{Kit_R} = w_{Kit_R} L_{Kit_R} / P_{Kit_R}$. The Geary-Khamis price of good K is then

$$p_K = \sum_{i=1}^{N} \frac{q_{Kit_R}}{\sum_{j=1}^{N} q_{Kjt_R}} \frac{P_{Kit_R}}{p_i}, \tag{33}$$

where p_i is the PPP price level in country i defined as

$$p_i = \frac{\sum_K P_{Kit_R} q_{Kit_R}}{\sum_K p_K q_{Kit_R}}. \tag{34}$$

Equations (33)-(34) need to be solved simultaneously for PPP price levels p_i and international prices p_K. In practice I use the matrix representation of the problem described in Diewert (1999).

Aggregate real income per worker of country i relative to the US in the reference year can than be computed as

$$\frac{\left(\sum_K p_K q_{Kit_R} / L_{it_R}\right)}{\left(\sum_K p_K q_{KUSt_R} / L_{USt_R}\right)}.$$

Similarly, the growth of aggregate productivity between the reference year t_R and year t in country i can be calculated as

$$\frac{\left(\sum_K p_K q_{Kit} / L_{it}\right)}{\left(\sum_K p_K q_{Kit_R} / L_{it_R}\right)}.$$

B.2 Calibration of Preference Parameters

The calibrated parameter vector $\hat{\omega} = \left\{\hat{\alpha}_A,\, \hat{\alpha}_M,\, \hat{\alpha}_S,\, \hat{\bar{c}}_A\right\}$ minimizes the GMM objective function $J(\omega)$:

$$\hat{\omega} = \arg\min_{\omega} J(\omega)$$

Below I describe how the function $J(\omega)$ is evaluated. Given a set of parameters $\{\alpha_A,\, \alpha_M,\, \alpha_S,\, \bar{c}_A\}$:

1. Find normalized preference weights parameters $\{\gamma_A,\, \gamma_M,\, \gamma_S\}$ such that U.S. expenditures in the reference year are consistent with household optimization given normalization $P_{KUSt_R} = 1$, i.e. find $\{\gamma_A,\, \gamma_M,\, \gamma_S\}$ satisfying:

$$\begin{aligned}
\frac{E_{AUSt_R}}{\sum_k E_{kUSt_R}} - \frac{1}{\sum_k E_{kUSt_R}} \left[\bar{c}_A + \left(\sum_k E_{kUSt_R} - \bar{c}_A\right) \frac{\gamma_A \left(\sum_k E_{kUSt_R} - \bar{c}_A\right)^{\alpha_A}}{\sum_k \gamma_k \left(\sum_k E_{kUSt_R} - \bar{c}_A\right)^{\alpha_k}}\right] &= 0 \\
\frac{E_{MUSt_R}}{\sum_k E_{kUSt_R}} - \frac{1}{\sum_k E_{kUSt_R}} \left[\left(\sum_k E_{kUSt_R} - \bar{c}_A\right) \frac{\gamma_M \left(\sum_k E_{kUSt_R} - \bar{c}_A\right)^{\alpha_M}}{\sum_k \gamma_k \left(\sum_k E_{kUSt_R} - \bar{c}_A\right)^{\alpha_k}}\right] &= 0\,. \\
\gamma_A + \gamma_M + \gamma_S - 1 &= 0
\end{aligned}$$

   Note that expenditures are computed as in (20) and do not depend on ω.

2. In the reference year solve for $\{P_{Aj},\, P_{Mj},\, P_{Sj}\}$ the system of equations

$$\begin{aligned}
\frac{E_{Aj}}{\sum_k E_{kj}} - \frac{1}{\sum_k E_{kj}}\left[P_A\bar{c}_A + \left(\sum_k E_{kj} - P_{Aj}\bar{c}_A\right)\frac{\gamma_A\left(\frac{\sum_k E_{kj}-P_{Aj}\bar{c}_A}{P_A}\right)^{\alpha_A}}{\sum_k \gamma_k\left(\frac{\sum_k E_{kj}-P_{Aj}\bar{c}_A}{P_k}\right)^{\alpha_k}}\right] &= 0 \\
\frac{E_{Mj}}{\sum_k E_{kj}} - \frac{1}{\sum_k E_{kj}}\left[\left(\sum_k E_{kj} - P_{Aj}\bar{c}_A\right)\frac{\gamma_M\left(\frac{\sum_k E_{kj}-P_{Aj}\bar{c}_A}{P_M}\right)^{\alpha_M}}{\sum_k \gamma_k\left(\frac{\sum_k E_{kj}-P_{Aj}\bar{c}_A}{P_k}\right)^{\alpha_k}}\right] & \quad 0 \quad ,\ j = 1, ..., N, \\
\frac{\sum_K p_K q_{Kj}/L_j}{\sum_K p_K q_{KUS}/L_{US}} - \frac{y_j}{y_{US}} &= 0
\end{aligned}$$

where the procedure for calculating Geary-Khamis international prices p_K is described in Section B.1 and where y_j denotes real GDP per capita in the data. In non-reference years replace the last equation in the system above with

$$\frac{\sum_K p_K q_{Kit}/L_{it}}{\sum_K p_K q_{Kit_R}/L_{it_R}} - \frac{y_{jt}}{y_{jt_R}} = 0.$$

3. Given wages from (20) and prices from previous step calculate labor productivities as $A_{Kit} = w_{Kit}/P_{Kit}$. Let t_l^i and t_f^i denote the last and first year that country i appears in the sample. Calculate annualized average log growth of A_{Kit} as $g_{Ki}(\omega) = \frac{1}{t_l^i - t_f^i}\log\left(\frac{A_{Kit_l^i}(\omega)}{A_{Kit_f^i}(\omega)}\right), \quad K \in \{A,\, M,\, S\}$.

4. Using time series described in Appendix A calculate annualized average log growth g_{Ki}^d of labor productivity in the data. Also create instruments x_K for sector K log productivity growth: a constant, log growth in sector K employment and log growth in expenditure share of sector K (all growth rates on an annualized basis).

5. Compute a vector of sample moments

$$h_n(\omega) = \left[\frac{1}{n}\sum_{j=1}^{n} x_{Aj}^{(1)}\left(g_{Aj}^d - g_{Aj}(\omega)\right) ... \frac{1}{n}\sum_{j=1}^{n} x_{Sj}^{(3)}\left(g_{Sj}^d - g_{Sj}(\omega)\right)\right]',$$

where $n = N^c$ is the sample size and N^c is the total number of countries appearing in the sample.

6. Given weighting matrix $\mathbf{W}$ evaluate the GMM objective function as

$$J(\omega) = n \cdot h_n(\omega)' \mathbf{W} h_n(\omega).$$

C Model Derivations and Extensions

C.1 Proof of Proposition 1

Suppose preferences are given by a CES utility function $U = \left(\sum_K \gamma_K^{\frac{1}{\varepsilon}} C_K^{\frac{\varepsilon-1}{\varepsilon}}\right)^{\frac{\varepsilon}{\varepsilon-1}}$ so the associated price index is $P = \left(\sum_K \gamma_K P_K^{1-\varepsilon}\right)^{\frac{1}{1-\varepsilon}}$. Indirect utility of a representative worker is then simply $V = E/P$, where E is the worker's expenditure. Comparing welfare in autarky and in trade equilibrium in country j we therefore have $V_j^A/V_j^T = \left(E_j^A/E_j^T\right)/\left(P_j^A/P_j^T\right)$. Notice that the expenditure must equal labor income both in autarky and in the trade equilibrium given the balanced trade assumption.

Consider first the model with labor wedges ξ_{Kj}, where the wedge does not depend on the trade regime. Define $\hat{w}_{Kj} \equiv w_{Kj}^A/w_{Kj}^T$. Then $E = \left(\sum_K w_K L_K\right)/L = w_M \left(\sum_K \xi_K L_K\right)/L$ and consequently $E_j^A/E_j^T = \hat{w}_{Mj}\left(\sum_K \xi_{Kj} L_{Kj}^A\right)/\left(\sum_K \xi_{Kj} L_{Kj}^T\right) = \hat{w}_{Mj}\Upsilon_j$. Next, using (31) and the fact that in autarky $\pi_{Kjj}^A = 1$ one can obtain $P_{Kj}^A = P_{Kj}^T \pi_{Kjj}^{-\frac{1}{\theta_K}\frac{1}{\beta_K}} \hat{w}_{Mj}$. Using the definition of the CES price index then gives

$$\frac{P_j^A}{P_j^T} = \hat{w}_{Mj}\left[\sum_K \gamma_K \left(\frac{P_{Kj}^T}{P^T}\right)^{1-\varepsilon}\left(\pi_{Kjj}^{-\frac{1}{\theta_K}\frac{1}{\beta_K}}\right)^{1-\varepsilon}\right]^{\frac{1}{1-\varepsilon}}.$$

But $\gamma_K\left(P_{Kj}^T/P^T\right)^{1-\varepsilon}$ equals the expenditure share of sector K in the model. Since we require the model to match this observable variable we can write

$$\frac{V_j^A}{V_j^T} = \Upsilon_j\left[\sum_K e_{Kj}^T\left(\pi_{Kjj}^{-\frac{1}{\theta_K}\frac{1}{\beta_K}}\right)^{1-\varepsilon}\right]^{-\frac{1}{1-\varepsilon}}.$$

Since by definition $GFT_j \equiv 1 - V_j^A/V_j^T$, we obtain (13).

Now suppose we calculate the gains from trade in a model abstracting from distortions. If the model matches the same observable data on trade intensities π_{Kjj} and expenditure shares e_{Kj}^T, then following the same steps as above but with $\xi_{Kj}^{ND} = 1$ we would obtain

$$\frac{V_j^{A,ND}}{V_j^{T,ND}} = \left[\sum_K e_{Kj}^T\left(\pi_{Kjj}^{-\frac{1}{\theta_K}\frac{1}{\beta_K}}\right)^{1-\varepsilon}\right]^{-\frac{1}{1-\varepsilon}}.$$

Noting that $GFT_j^{ND} \equiv 1 - V_j^{A,ND}/V_j^{T,ND}$ then immediately gives $GFT_j = 1 - \Upsilon_j\left(1 - GFT_j^{ND}\right)$, which is the desired result (12).

The term Υ_j can be rewritten in another useful way. Let $\delta_{Kj}^T = D_{Kj}/\sum_K w_{Mj}^T \xi_K L_K$ denote the sector-K deficit to GDP ratio in the baseline trade equilibrium, where balanced aggregate trade requires $\sum_K \delta_{Kj}^T = 0$. Knowledge of deficit intensities δ_{Kj}^T and and expenditure shares e_{Kj}^T implies knowledge of sectoral VA shares in the model. Given wedges ξ_{Kj}, VA shares in turn imply values of labor shares l_{Kj}. Thus one can derive

$$\Upsilon_j = \frac{\sum_K \frac{e^T_{Kj} - \delta^T_{Kj}}{\xi_{Kj}}}{\sum_K \frac{e^A_{Kj}}{\xi_{Kj}}}.$$

But the counterfactual autarky expenditure shares e^A_{Kj} can be computed form the knowledge of e^T_{Kj} and changes in prices in moving from trade to autarky as

$$e^A_{Kj} = \frac{e^T_{Kj} \pi_{Kjj}^{-\frac{1}{\theta_K}\frac{1}{\beta_K}(1-\varepsilon)}}{\sum_k e^T_{kj} \pi_{kjj}^{-\frac{1}{\theta_k}\frac{1}{\beta_k}(1-\varepsilon)}}.$$

Consequently, Υ_j can be expressed purely in terms of data observed in the baseline trade equilibrium

$$\Upsilon_j = \frac{\sum_K \frac{e^T_{Kj} - \delta^T_{Kj}}{\xi_{Kj}}}{\sum_K \frac{e^T_{Kj}}{\xi_{Kj}} \frac{\pi_{Kjj}^{-\frac{1}{\theta_K}\frac{1}{\beta_K}(1-\varepsilon)}}{\sum_k e^T_{kj} \pi_{kjj}^{-\frac{1}{\theta_k}\frac{1}{\beta_k}(1-\varepsilon)}}}. \tag{35}$$

C.2 Incorporating Tariffs

The baseline version of the model treats transport costs τ_{Kji} as iceberg costs so that moving goods between countries results in a real loss of output. Below I present an extension of the model that incorporates also policy barriers in the form of tariffs.

Let the trade costs have two components: $\tau_{Kji} = d_{Kji}(1 + t_{Kji})$, where d_{Kji} is the real iceberg cost and where t_{Kji} is an ad-valorem tariff rate on sector K imports to country j. I assume that the net tariff revenue R_j is redistributed lump-sum to consumers. Taking aggregate deficits D_j as exogenously fixed as before the final demand net of consumption requirement in country j can be written as

$$\tilde{X}^F_j = R_j + w_{Aj}L_{Aj} + w_{Mj}L_{Mj} + w_{Sj}L_{Sj} + D_j - L_j \sum_K P_{Kj}\bar{c}_K. \tag{36}$$

Denoting by X_{Kj} the total spending on sector K in country j and by X_{Kji} the revenue received by country i producers from exports to j, with some algebra we can establish that the tariff revenue can be expressed as

$$\begin{aligned} R_j &= \sum_{K\in\{A,M\}} \sum_i t_{Kji} X_{Kji} = \sum_{K\in\{A,M\}} \sum_i t_{Kji} \frac{\pi_{Kji}}{(1+t_{Kji})} X_{Kj} \\ &= \sum_{K\in\{A,M\}} \left\{ (1-\beta_K)\beta_K^{-1} w_{Kj}L_{Kj} + L_j P_{Kj} \left[\bar{c}_K + \frac{\gamma_K \left(\frac{\tilde{X}^F_j/L_j}{P_K}\right)^{\alpha_K+1}}{\sum_k \gamma_k \left(\frac{\tilde{X}^F_j/L_j}{P_k}\right)^{\alpha_k}} \right] \right\} \sum_i t_{Kji} \frac{\pi_{Kji}}{(1+t_{Kji})}. \end{aligned} \tag{37}$$

Equations (36) and (37) can be solved for R_j and $\tilde{X}^F_j$ so that all equilibrium conditions can be expressed in terms of the same variables as in the baseline model. The main difference is that the market clearing conditions in tradable sectors (9) now take the form

$$w_{Ki}L_{Ki} = \sum_j \frac{\pi_{Kji}}{(1+t_{Kji})} \left\{ (1-\beta_K)\, w_{Kj}L_{Kj} + \beta_K L_j P_{Kj} \left[\bar{c}_K + \frac{\gamma_K \left(\frac{\tilde{X}_j^F/L_j}{P_K} \right)^{\alpha_K+1}}{\sum_k \gamma_k \left(\frac{\tilde{X}_j^F/L_j}{P_k} \right)^{\alpha_k}} \right] \right\},\ K \in \{A,\, M\}\,.$$

D Alternative Measures of Wedges

In this paper I take differences in value added per worker across sectors within a country as indicative of distortions to labor allocation, consistent with the model's assumption of homogeneous labor being the only primary factor of production. In this part of the Appendix I briefly sketch out the implications of omitting other factors of production for the measurement of labor distortions.

Suppose that production requires inputs of homogeneous labor and capital. To make the point clearly, keep the assumption of perfect competition and suppose that capital and labor are combined using Cobb-Douglas technology with constant returns to scale, so that the cost function for an individual variety is given by

$$\frac{c_{Ki}}{z_{Ki}(h)} = \frac{\left(w_{Ki}^{\eta_K} r_{Ki}^{1-\eta_K} \right)^{\beta_K} P_{Ki}^{1-\beta_K}}{z_{Ki}(h)},$$

where η_K is the share of labor in value added in sector K. Cobb-Douglas technology is a natural benchmark since it is a standard specification in growth and development accounting exercises and because it is typically used in theoretical work on structural transformation since it is consistent with balanced aggregate growth. Labor share η_K is sector-specific but assumed to be common for all countries and across time.

Under those assumptions we can use the data on sector VA and employment to compute the correct measure of the labor wedge as:

$$\tilde{\xi}_{Ki} = \frac{VMPL_{Ki}}{VMPL_{Mi}} = \frac{w_{Ki}}{w_{Mi}} = \frac{\eta_K VA_{Ki}/L_{Ki}}{\eta_M VA_{Mi}/L_{Mi}}.$$

Observe that given factor shares, value added and employment data are sufficient to calculate the wedge between $VMPL$ across sectors, regardless of whether there are distortions to capital allocation.

The relationship between the wedge ξ_{Ki} I measure in (16) and the "true" wedge is

$$\xi_{Ki} = \frac{\eta_M}{\eta_K}\tilde{\xi}_{Ki},$$

that is my wedge is proportional to the true wedge. Thus incorporating other factors of production with C-D technology can justify differences in VA per worker across sectors, but to explain the nontrivial distribution of those differences across countries and over time while maintaining the assumptions listed above we still need some source of distortions to efficient allocation of labor.

To gauge the magnitude of bias in calculating distortions due to ignoring other factors of production and labor heterogeneity I calculated alternative measures of wedges for a subset of countries. I use the data for a subsample of countries for which Socio-Economic Accounts tables of the World Input-Output Database (WIOD) [Timmer (2012)] project are available. Those tables contain,

Table 12: Alternative Measures of Wedges

Wedge	(1) Agr. $\bar{\tilde{\xi}}_A$	(2) $Corr\left(\xi_A, \tilde{\xi}_A\right)$	(3) Ser. $\bar{\tilde{\xi}}_S$	(4) $Corr\left(\xi_S, \tilde{\xi}_S\right)$
benchmark: VA/worker	0.45	1.00	0.84	1.00
VA/worker	0.42	0.88	0.84	0.92
VA/hour	0.42	0.81	0.87	0.83
lab. comp./hour	0.46	0.66	0.96	0.68
lab. comp./hour H skill	0.49	0.47	0.90	0.47
lab. comp./hour M skill	0.51	0.55	0.90	0.64
lab. comp./hour L skill	0.51	0.56	0.86	0.63

Notes: $\bar{\tilde{\xi}}_K$ denotes the geometric mean of wedge in sector K across 251 observations for up to 25 countries over 1995-2005. $Corr\left(\xi_K, \tilde{\xi}_K\right)$ gives the correlation between the benchmark wedge used in the calibration and alternative measures.

among other, data on value added, total employment, hours worked and total labor compensation by sector. In addition data on hours and labor compensation is also available split by three skill groups (High, Medium and Low). I had to eliminate a few countries for which reported labor compensation exceeds the value added of industry, leaving the final sample of up to 25 countries over the period 1995-2005.

Columns 1 and 3 of Table 12 report the geometric means of wedges in agriculture and in services for various calculations. The first row gives the numbers from the benchmark calculation in the paper - based on smoothed series of value added and total employment - restricted to the current subsample. The remaining rows use raw data from WIOD. The second entry reports the same calculation but using the WIOD data. Different data sources and handling explains the small differences with the first row. The third row controls for differences in hours worked by sector and shows wedges based on value added per hour. The fourth row in addition controls for differences in labor shares across sectors and calculates wedges based on the labor compensation component of value added per hour worked. The last three rows attempt to control for skill differences across sectors by focusing on differences in labor compensation per hour worked within each of the three skill groups. None of this adjustments significantly reduces the large gap between agriculture and manufacturing. Columns 2 and 4 report the correlation between the benchmark wedge used in the paper and the alternative measures of distortions. In all cases there is a strong positive correlation between the two measures.