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Essays on International Trade

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Abstract

This thesis consists of three chapters on the economic effects of agricultural and non-agricultural trade. The first chapter asks whether the observed low trade intensity of agricultural goods is caused by high trade costs or small gains from agricultural trade. By empirically estimating structural equations from a trade model, I find that it is largely due to high trade costs. I also find large variation in relative efficiency of producing agricultural goods, which suggests that lower agricultural trade costs could lead to large gains from trade. The second chapter asks how large are the gains from lower trade costs in the presence of the "Food Problem". I extend the Eaton-Kortum trade model to include a tradeable agriculture sector, minimum consumption and home production of agricultural goods. The calibrated model implies much larger gains from trade for poor countries than prior studies. The main reason for these gains is that intra-sectoral trade leads poor countries to specialize in a set of agricultural goods with high efficiency and inter-sectoral trade enables them to reallocate labor to manufacturing, which often is their comparative advantage sector. The third chapter quantitatively evaluates the potential impact of removing China's Hukou system, which restricts rural-urban migration in China, on the world economy. I find that removing Hukou could increase China's income by 4.7%, and would substantially impact some of China's small neighboring economies. This is because removing Hukou increases the relative price of agricultural goods, which benefits net agricultural exporters such as Thailand and hurts net agricultural importers such as Sri Lanka and Bangladesh.

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I want to dedicate this thesis to my grandma, who has been very close to me since my birth. She passed away about four years ago, when I was studying at Western. I am certain that she is smiling at me in heaven as I am writing this thesis.

London, Canada Kai Xu
August 13, 2011

To my grandparents, my parents, my wife Cong Li,
and my son Howard Xu

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Chapter 1

Introduction

My thesis consists of three related essays on international trade, with particular focus on the economic effects of agricultural and non-agricultural trade. The first essay is an empirical study on the causes of the observed low trade intensity of agricultural goods. In the second essay, I evaluate how large are the gains from trade in the presence of the food problem. In the third essay, I study the potential impacts of removing China's Hukou system on both China's economy and other economies in the world.

The first essay, *Why Are Agricultural Goods Not Traded More Intensively: High Trade Costs or Low Productivity Variation?*, empirically studies the sizes of agricultural trade costs and productivity variation in the agriculture sector. In a general Ricardian trade model, I identify these two factors as possible causes of the observed low trade intensity of agricultural goods. Using data on bilateral trade flows, prices of agricultural goods, and sectoral production from a sample of 46 countries, I estimate the variation of agricultural productivity as well as trade costs on agricultural and manufactured goods. I find that trade costs are substantial, with agricultural trade costs roughly twice as large as manufacturing trade costs. Moreover, consistent with the existing literature, I find that distance is the dominant part in the estimated trade costs. Lastly, relative to existing estimates of the heterogeneity of manufacturing productivity, the heterogeneity of agricultural productivity is large. These findings suggest that high trade costs are the main impediments to agricultural trade and that there exist large unrealized gains from trading agricultural goods.

The second essay, *Gains from Trade and the Food Problem*, finds that the food problem can lead to substantial gains from increased trade in agricultural goods. According to the food problem hypothesis, many countries are poor because they must devote large fractions of productive resources in the unproductive agriculture sector to satisfy subsistence needs for food. To quantify the potential gains from trade in the presence of the food problem, I extend the Eaton-Kortum trade model to include a tradeable agriculture sector, minimum consumption and home production technology of agricultural goods. For a sample of 46 countries, the model is calibrated to observed bilateral trade flows, sectoral employment shares, and relative real GDP per capita. Counterfactual exercises produce three key findings. First, in frictionless trade, the average increase in real GDP per capita is more than 330% for countries in the highest quartile of agricultural employment shares, while it is 70% for countries in the lowest quartile. Second, for poor countries with the food problem, reducing trade costs on agricultural goods is particularly important for increasing their income levels: a 20% reduction on agricultural trade costs leads to 10% average increase in real GDP per capita, while lowering agricultural trade costs to those of manufacturing leads to 22% average increase in real income. Finally, poor countries' potential gains from trade can be underestimated by as much as 50% in a model without subsistence needs and home production.

The third essay, *Barriers to Labor Mobility and International Trade: The Case of China*, quantitatively evaluates the potential impacts of removing China's Hukou system on the world economy. By denying migrant workers the right to health benefits and housing, China's Household Registration (Hukou) system presents a significant distortion to the Chinese labor market that discourages the reallocation of its labor from agriculture to non-agriculture. I find that the elimination of Hukou could increase China's real income per capita by about 4.7%. Moreover, although for most countries the impact of removing Hukou is modest (less than 1% changes in real income per capita), substantial changes in real income could take place for China's small neighboring economies. For example, the decreases in real GDP per capita are 2.7%, 3.2%, and 4.1% for Bangladesh, Sri Lanka, and Vietnam, while Thailand stands to enjoy a 3.8% increase in its income.

Chapter 2

Why Are Agricultural Goods Not Traded More Intensively: High Trade Costs or Low Productivity Variation?

2.1 Introduction

Agricultural goods are traded less than manufactured goods. In 1997, the total value of manufacturing trade was more than 8 times larger than that of agricultural trade.[1] This is despite that the value of manufacturing production was less than 4 times larger than that of agricultural production in 1997. Therefore, more than half of the difference in trade volume between agricultural goods and manufactured goods is due to the lower trade intensity of agricultural goods. To see this, consider a common measure of trade intensity: the

[1]The year 1997 is chosen because the analysis in this essay is based on 1997 data. If anything, the differences between agricultural trade and manufacturing trade have been even larger after 1997.

ratio of the sum of total exports and imports to gross production. In 1997 and for a sample of 48 countries, trade intensity of agricultural goods was without exception lower than that of manufactured goods. Furthermore, agricultural goods also tend to be produced more locally. For the same group of 48 countries, 33 (about 69%) of them have a higher domestic share of production in agricultural goods than manufactured goods.

Standard trade theories offer two possible explanations to the low trade intensity of agricultural goods. First, trade barriers on agricultural products could be high. Second, the degree of comparative advantage in agriculture could be so low that gains from trading agricultural goods are small. As a result, countries do not have much incentive to engage in agricultural trade with each other, regardless the trade barriers on agricultural goods.

It is important to determine the relative importance of these two factors, as agricultural goods both play an essential economic role and their production often employs the majority of productive resources in low income countries.[2] On the one hand, if high agricultural trade costs are the main impediments, it suggests that countries may not be fully enjoying the gains from agricultural trade because of high trade barriers. As a result, efforts should be directed to measures that can lower trade barriers on agricultural goods. On the other hand, if the degree of comparative advantage in agriculture is small which

[2] For instance, in 1997, the poorest five countries in the Penn World Table 6.3 on average devote 58% of their workforce to agriculture, as compared to less than 4% for the richest five countries. See Chapter 3 *Gains from Trade and the Food Problem* for more a detailed discussion.

implies the lack of gains from trading agricultural goods, such practices will not be fruitful.

Motivated by the potential importance of agricultural trade and the lack of it, this essay asks why agricultural goods are not traded more intensively. To quantitatively disentangle the two possible causes, I develop a simple general equilibrium trade model similar to that in Eaton and Kortum (2002). In addition to the tradeable manufacturing sector in the Eaton-Kortum model, the model in this essay also includes a tradeable agriculture sector. In the model, bilateral trade flows are determined by three factors: each country's production costs, bilateral trade costs, and the variation of productivity, which governs the degree of comparative advantage in the tradeable sectors. An advantage of using the Eaton-Kortum framework is that one can derive log-linear gravity equations that relate bilateral trade flows to these three factors. The parameters in these structural equations can then be estimated by common estimation methods such as ordinary least-squares (OLS).

However, given that bilateral trade flows are *jointly* determined by trade costs and productivity variation, one faces the challenge of separating their effects from one another. This is important because the observed low trade intensity of agricultural goods can be rationalized by either small variation of productivity in the agriculture sector or large agricultural trade costs, and hence the estimation of one factor directly affects the estimation of the other. For example, if one finds that the variation of agricultural productivity is large, the fact that agricultural goods are not traded intensively must necessarily mean that agricultural trade costs are large. As a result, an underestimated variation of agricultural productivity will lead to underestimations of agricultural trade costs.

To address this concern, I follow an approach in Eaton and Kortum (2002), where the estimations are carried out sequentially. First, the variation of agricultural productivity is estimated with *independent* measures of agricultural trade costs. Specifically, bilateral trade costs are approximated by observed maximum price difference on individual agricultural goods between two countries. This approach works, as Eaton and Kortum argue, because a simple no-arbitrage condition ensures that price differences cannot exceed bilateral trade costs, and hence the maximum price difference is a good proxy for trade costs. Second, using the estimated value of the productivity variation, I estimate bilateral trade costs from structural equations that relate bilateral trade flows to countries' production costs, variation of productivity, and bilateral trade costs.

The estimations in this essay are based on data on bilateral trade flows and prices of agricultural goods from a sample of 46 countries. There are three main findings. First, relative to existing estimates of the variation of manufacturing productivity in the literature, I find that the variation of agricultural productivity is large. Specifically, my baseline estimate of the variation of agricultural productivity implies that the distribution of agricultural efficiency has a standard deviation that is 75% larger than that of the distribution of manufacturing efficiency in Eaton and Kortum (2002) and 17% larger than those in Waugh (2009).

Second, consistent with the existing literature, I find that distance is the dominant part in the estimated trade costs, and that its effects are large. After dividing bilateral distance into six intervals, I find that, as bilateral distance increases, its effects on increasing trade costs become larger. Specifically, for every one dollar worth of agricultural and manufactured goods, distance adds at least 1.89 and 0.89 dollars to the cost of shipping from one country to another. On the other hand, for a pair of countries in the largest distance interval, the effects of distance on increasing agricultural and manufacturing trade costs are equivalent to 4.89 and 2.65 dollars.

Third, while trade costs on both tradeable goods are substantial, agricultural trade costs are much larger than manufacturing trade costs. Specifically, for every one dollar worth of agricultural goods, trade costs are at least 2.7 dollars and can be as large as 5.48 dollars. On the other hand, trade costs on manufactured goods range from 1.77 to 2.65 dollars. This indicates that agricultural trade costs are at least twice as large as manufacturing trade costs. Combined with the finding of large variation of agricultural productivity, it suggests that the low trade intensity of agricultural goods is largely due to high agricultural trade costs.

The estimation strategy employed in this essay largely addresses what Anderson and van Wincoop (2004) identify as the two main problems in measuring and inferring trade costs. First, by estimating gravity equations, the estimated trade costs in this essay are broad measures of trade costs, which include "all costs incurred in getting a good to a final user". This is important, they argue, since direct measures of trade costs, such as policy barriers, transport costs, and distribution costs, are "remarkably sparse and inaccurate" and make up only a small portion of the costs incurred by trading partners. Second, the model implied gravity equations in this essay satisfy what Anderson and van Wincoop (2004) categorize as "Theory-Based Gravity" and the property of "trade separability". Namely, estimations are based on equations that are derived from a general equilibrium trade model, and their existence is independent of the allocation of production and consumption in the model. As Anderson and van Wincoop (2003) show, unlike the traditional gravity equations, gravity equations with the aforementioned properties tend not to suffer from the problem of omitting variables and yield unbiased estimates of trade costs.

This essay is closely related to the large literature on measuring and estimating agricultural trade costs. However, most existing studies suffer from at least one of the two problems described in Anderson and van Wincoop (2004).

For example, in studies such as van der Mensbrugghe and Beghin (2004), agricultural trade costs are computed using data on tariffs, quotas, and price subsidies in agriculture. As a result, their baseline agricultural trade costs are much lower. The ad valorem agricultural trade costs in van der Mensbrugghe and Beghin (2004) range from 16% to 38%, which are drastically smaller than the estimates provided by this essay, which range from 150% to 413%. On the other hand, studies such as Blake, Rayner, and Reed (1999), estimate agricultural trade costs from traditional gravity equations that are not derived from a trade model. As a result, the gravity equations which the estimations are based on appear ad hoc and are prone to specification errors.

This essay is also closely related to a large gravity literature, which investigates the determinants of observed trade flows. In particular, this essay is most closely related to studies that estimate trade barriers using structural models. For instance, Helpman, Melitz, and Rubinstein (2007) derive gravity equations from the Melitz model and study barriers to bilateral trade flows. This essay differs in that it explicitly considers agricultural trade as a separate category in the general merchandize trade and is based on a very different structural model. There are also several studies that utilize the Eaton-Kortum framework to estimate trade barriers. Examples include Eaton and Kortum (2002), Waugh (2009), and Fieler (2010). However, all these studies abstract from agricultural trade and often equate merchandize trade to trade in manufactured goods.

Tombe (2011) is closely related to this essay. As part of the quantitative exercise, Tombe estimates agricultural and manufacturing trade costs using structural equations from the Eaton-Kortum framework that are similar to those in this essay. However, unlike Tombe (2011) where the value of the variation of agricultural productivity is *imposed on*, this essay *estimates* the variation of agricultural productivity by utilizing data on producer prices of individual agricultural goods.[3] The estimation results in this essay indicate that in Tombe (2011) the true variation of productivity in agriculture is likely to be underestimated by about 50% and, consequently, agricultural trade costs are underestimated by at least 50%. This finding highlights the need to estimate *both* the impacts of trade costs and the variation of productivity in the tradeable sectors.

The rest of the essay proceeds as follows. Section 2.2 details three empirical facts in support of the low trade intensity of agricultural goods. Section 2.3 describes the model. Section 2.4 details the data and the estimation. Section 2.5 concludes.

[3]Specifically, Tombe (2011) sets the variation of agricultural productivity to 0.14, where the baseline estimated value in this essay is 0.21. One reason that the variation of agricultural productivity is not estimated in Tombe (2011) is that, as the author argues, available data on the prices of tradeable goods including agricultural goods are often retail prices, which make them unsuitable for the estimation. This essay addresses this problem by using producer prices of agricultural goods.

2.2 Empirical Evidence on the Low Trade Intensity of Agricultural Goods

In this section I document three empirical facts in support of the low trade intensity of agricultural goods. First, in terms of trade volume, agricultural goods are traded much less than manufactured goods, and that it cannot be entirely accounted for by the larger size of manufacturing production. Second, for a sample of 48 countries, trade intensity of agricultural goods is lower than that of manufactured goods. Last, relative to that of manufacturing production, the domestic share of agricultural production is higher for a large number of countries.

As a first look at the data, I examine how agricultural trade compares to manufacturing trade as a share of merchandize trade and whether the differences are due to the different size of their production. According to trade data from Food and Agriculture Organization of the United Nations (FAO), in 1997 the volume of world agricultural trade was about 8.3% of total world merchandize trade. On the other hand, data from the World Bank's World Development Indicators (WDI) show that in the same year the volume of world manufacturing trade was about 76.2% of total world merchandize trade. This means that, in terms of trade volume, manufacturing trade was about 818% larger than agricultural trade.

While it is true that the world also produces more manufactured goods, the difference between manufacturing production and agricultural production cannot fully account for the large difference in trade volume. In particular, production data from the WDI show that, in 1997, agriculture as a share of world GDP was about 4.2% while it was 20.3% for manufacturing. This means that the value of manufacturing production was about 383% larger than that of agricultural production. Therefore, the difference in the value of production between agriculture and manufacturing accounts for less than half of the difference in trade volume. This suggests that, agricultural goods are not only traded less than manufactured goods, but also traded *less intensively* than manufactured goods.

The finding that trade intensity of agricultural goods is lower than that of manufactured goods is robust and holds true for a wide range of countries. To see this, consider a common measure of trade intensity: the ratio of the sum of total exports and imports to gross production. Based on 1997 data from the Global Trade Analysis Project (GTAP) data base (version 5), Figure 2.1 compares the trade intensity of agricultural goods to that of manufactured goods for a group of forty-eight countries.[4] This group of countries is a representative sample of the individual economies in the world, as it covers a wide range of income levels, from 0.03 (Uganda) to 0.82 (Denmark) relative to the U.S.'s real GDP per capita.

One can clearly see that *all* observations are above the forty-five degree line

[4]48 is the maximum number of countries GTAP (version 5) has data on.

in Figure 2.1. This indicates that for *all* sample countries agricultural goods are traded less intensively than manufactured goods. Moreover, for 39 of the 48 countries (more than 80% of the sample), this measure of trade intensity of manufactured goods is at least twice as large as that of agricultural goods.

The two empirical facts discussed above are consistent with a large number of studies in the literature of agricultural trade, which also find that agricultural goods are traded less intensively than other types of tradeable goods. For example, after examining detailed trade data on agricultural goods and other traded goods, Aksoy (2004) concludes that the "trade-to-output ratios in agriculture" are substantially smaller than those in"manufacturing and services". Focusing on trade policies, the author argues that this is consistent with the fact that the degree of trade liberalization in manufacturing has been much higher than that in agriculture since 1990.

Besides trade intensity, one can also compare the ratio of self-sufficiency of agricultural goods to that of manufactured goods. Calculated as the ratio of gross production to gross production minus net exports (total exports minus total imports), it measures the share of a country's supply of a certain good originates from its own production. From Figure 2.2, one can see that for most countries, this ratio is higher for agricultural goods than manufactured goods. Specifically, 33 of the 48 countries (about 70% of the sample) have a higher self-sufficiency ratio on agricultural goods than manufactured goods. This means that for these countries the domestic share of agricultural production is higher than that of manufacturing production.

In summary, the three empirical facts discussed above show that, relative to other tradeable goods such as manufactured goods, agricultural goods are traded less intensively.

2.3 The Model

The model extends the multi-country Ricardian trade model in Eaton and Kortum (2002) to include two tradeable sectors: agriculture and manufacturing. As in Dornbusch, Fischer, and Samuelson (1977), this framework features a continuum of tradeable goods in each tradeable sector.

2.3.1 Tradeable Goods Sectors

The world economy consists of n countries. Within each country i, there are two tradeable sectors: agriculture (a) and manufacturing (m). A continuum of intermediate goods, indexed by $x^a, x^m \in [0,1]$, exist in each tradeable sector. The production of intermediate agricultural good $q_i^a(x^a)$ and intermediate manufactured good $q_i^m(x^m)$ is constant-return and given by:

$$
\begin{aligned}
q_i^a(x^a) &= z_i(x^a)^{-\theta^a} c_i^a \, , \\
q_i^m(x^m) &= z_i(x^m)^{-\theta^m} c_i^m \, ,
\end{aligned}
$$

where $z(x^a)^{-\theta^a}$ and $z(x^m)^{-\theta^m}$ are the productivities used in producing x^a and x^m. c_i^a and c_i^m are the unit costs of producing each intermediate tradeable good x^a and x^m in country i. It is assumed that θ^a and θ^m are the same across countries, i.e. both parameters are sector-specific but not country-specific.

2.3.2 Distribution of Productivity

As in Eaton and Kortum (2002), productivities $z_i(x^a)$ and $z_i(x^m)$ are assumed to be random variables independently drawn from a density function that is exponential with parameters λ_i^a and λ_i^m. $z_i(x^a)$ and $z_i(x^m)$ are then amplified by the parameters θ^a and θ^m.

In this environment, the parameters λ_i^a and λ_i^m govern country i's average efficiency level in the agriculture and manufacturing sector. The larger the λ_i^a or λ_i^m, the more competitive country i tends to be in the respective tradeable sector. Parameters θ^a and θ^m, on the other hand, control the dispersion of the distribution from which productivities $z_i(x^a)$ and $z_i(x^m)$ are drawn. As a result, θ^a and θ^m directly determine the degree of comparative advantage in their respective sector. The larger θ^a or θ^m is, the more dispersed the productivity draws are relative to the mean. Hence countries are more likely to trade with each other, as there exist larger gains from trade.

In each tradeable sector of country i there exists a firm that simply aggregates the tradeable intermediate goods. The productions of aggregate agricultural and manufactured good are given by:

$$
\begin{aligned}
Q_i^a &= \left[\int_0^\infty q_i^a (x^a)^{1-1/\eta} \phi(x^a) dx^a \right]^{\eta/(\eta-1)}, \\
Q_i^m &= \left[\int_0^\infty q_i^m (x^m)^{1-1/\eta} \phi(x^m) dx^m \right]^{\eta/(\eta-1)}.
\end{aligned}
$$

2.3.3 International Trade

Trade costs are assumed to take the form of "iceberg" trade costs, which are positive ad valorem costs required to ship one unit of tradeable good from one country to another country. These trade costs are the same within sectors, but different across sectors.

Respectively, let τ_{ij}^a and τ_{ij}^m be the trade costs on intermediate agricultural goods and intermediate manufactured goods, from country j to country i. It is assumed that $\tau_{ij} > 1$ for $j \neq i$ and $\tau_{ii} = 1$ for all i, as well as that it obeys the triangle inequality: $\tau_{ij} \leq \tau_{ik}\tau_{kj}$ for all i, j, k. Therefore, given trade costs τ_{ij}^a and τ_{ij}^m, the prices of country i importing tradeable goods x^a and x^m from country j are:

$$
\begin{aligned}
p_{ij}^a(x^a) &= (x^a)^{\theta a} c_j^a \tau_{ij}^a , \\
p_{ij}^m(x^m) &= (x^m)^{\theta m} c_j^m \tau_{ij}^m .
\end{aligned}
$$

When country i is open to trade, the producer that delivers the lowest price for $q^a(x^a)$ or $q^m(x^m)$ in i captures the market for that particular good:

$$p_i^a(x^a) = \min\{p_{ij}^a(x^a) : j = 1, ..., n\}\,, \tag{2.1}$$

$$p_i^m(x^m) = \min\{p_{ij}^m(x^m) : j = 1, ..., n\}\,. \tag{2.2}$$

Let P_i^a and P_i^m be the prices of aggregate agricultural good and aggregate manufactured good in country i. By making use of the properties of the extreme value distribution, one can show that the prices of the aggregate agricultural goods and manufactured goods are:

$$P_i^a = \Upsilon\left[\sum_{j=1}^{n}(c_j^a\tau_{ij}^a)^{-1/\theta^a}\lambda_j^a\right]^{-\theta^a}\,, \tag{2.3}$$

$$P_i^m = \Upsilon\left[\sum_{j=1}^{n}(c_j^m\tau_{ij}^m)^{-1/\theta^m}\lambda_j^m\right]^{-\theta^m}\,, \tag{2.4}$$

where Υ is a collection of constants.[5]

Let D_{ij}^a and D_{ij}^m be country j's share of country i's total spending on agricultural goods and manufactured goods. One can show that:

$$D_{ij}^a = \frac{(c_j^a\tau_{ij}^a)^{-1/\theta^a}\lambda_j^a}{\sum_{k=1}^{n}(c_k^a\tau_{ik}^a)^{-1/\theta^a}\lambda_k^a}\,, \tag{2.5}$$

$$D_{ij}^m = \frac{(c_j^m\tau_{ij}^m)^{-1/\theta^m}\lambda_j^m}{\sum_{k=1}^{n}(c_k^m\tau_{ik}^m)^{-1/\theta^m}\lambda_k^m}\,. \tag{2.6}$$

[5]See Alvarez and Lucas (2007) for a detailed derivation.

2.4 Estimating Variation of Agricultural Productivity and Sectoral Trade Costs

The estimation in this section proceeds in two steps. First, the variation of technology in agriculture is estimated with *independent* measures of agricultural trade costs. Second, after deriving the values of sectoral productivity variation, trade costs on agricultural and manufactured goods are estimated. The estimation is based on model implied structural gravity equations that relate bilateral trade flows to the variation of productivity and trade costs in each tradeable sector.

2.4.1 Data

Data from a group of 46 countries are used, and they are from 1997. Data on the bilateral trade flows and gross productions of agricultural and manufactured goods are from the Global Trade Analysis Project (GTAP). These data are mainly used in constructing bilateral trade shares D_{ij}^{a} and D_{ij}^{m} as:

$$\begin{aligned} D_{ij}^{a,m} &= \frac{\text{Imports}_{ij}}{\text{Gross Agricultural Production} - \text{Total Exports}_i + \text{Imports}_i}, \\ D_{ii}^{a,m} &= 1 - \sum_{j \neq i}^{n} D_{ij}^{a,m}. \end{aligned}$$

Data on the prices of individual agricultural goods are used in the estimation of the variation of technology in agriculture. They are from the PriceSTAT database of the Food and Agriculture Organization of the United Nations

(FAO). PriceSTAT is a database on the prices of over 140 individual agricultural goods for more than 130 countries. These price data are producer price and denominated in the unit of either local currency per tonne or U.S. dollar per tonne, and each observation corresponds to the individual agricultural price $p_i^a(x^a)$ in equation (2.1).

Lastly, data on distance, border, and language are from Centre D'Etudes Prospectives Et D'Informations Internationales (http://www.cpeii.fr).

2.4.2 High Agricultural Trade Costs and Large Variation of Agricultural Productivity: Evidence from Price Data

Before estimating the relative effects of trade barriers and the variation of agricultural productivity in determining the low trade intensity of agricultural goods, in this section I examine how the prices of agricultural goods differ across countries. Given that they are producer prices that exclude most types of distribution costs and are expressed in the same currency and same unit ($USD/tonne), the price data from FAO enable cross-country comparison on agricultural prices and their implied trade barriers.

I first examine how the prices of the same individual agricultural goods differ across countries. For the 48 countries sampled by Figure 2.1, I calculate price difference as the ratio of the prices of the same agricultural good in two countries. This calculation is carried out for all agricultural goods in the FAO database as long as price data are available for a pair of countries. In total, there are 50,380 observations.[6] Summary statistics of the calculated price differences are provided in Table 2.1, and Figure 2.3 plots the distribution of all calculated price ratios.

From Table 2.1 and Figure 2.3, one can see that prices of agricultural goods differ substantially across countries. For example, more than 28% of the observed price differences exceed 2.5, which indicates that the price of the same agricultural good in one country is more than 150% larger than in another country. Moreover, it is not uncommon to observe large price differences. About 4.3% of the sample (2166 observations) have a price ratio larger than 7.5 - a 650% price difference between two countries. More than 1% of the sample (more than 503 observations) are larger than 12.5, which indicates the price of the same agricultural good in one country is more than 11 times larger than in another country.

To further focus the discussion on cross-country differences in agricultural prices, Figure 2.4 surveys the prices of eight agricultural goods.[7] These eight agricultural goods are chosen because they have the most observations among all the agricultural goods in the FAO database. Figure 2.4 clearly shows that

[6]Except for the case of two countries having the exact same price for an agricultural good, for each pair of countries on one agricultural good there will be two calculated price ratios - one greater than one and another smaller than one. To avoid repetitive reporting, I only include the ones that are equal or greater than one.

[7]Summary statistics are provided in Table 2.2.

the law of one price does not hold. It is not uncommon for the price of the same agricultural good in two countries to differ by more than 200%. It is worth noting that the country with the highest price or with the lowest price changes constantly. No particular country is consistently having high or low prices for its agricultural goods.

That the law of one price fails to hold suggests that there are significant barriers to trading agricultural goods. If this were not the case, then the no-arbitrage condition would imply that the prices of individual agricultural goods should be similar across countries. Figure 2.3 and 2.4 clearly reject this notion.

After examining *absolute* agricultural prices *across* countries, I turn to *relative* prices of agricultural goods *within* each country. If within a country input costs are similar (as in this essay's model) for a pair of agricultural goods, the ratio of output prices should be approximately equal to relative productivity. Therefore, the distribution of observed relative agricultural prices provides a measure of the dispersion of productivity in agriculture.

Figure 2.5 surveys the relative prices of five pairs of agricultural goods, and the summary statistics are provided in Table 2.3.[8][9] A similar pattern as Figure 2.4 is observed. The relative prices of the five pairs of agricultural goods all have wide distributions, suggesting that relative prices of agricultural goods

[8]Again, these five pairs of agricultural goods are chosen for no particular reason other than they have the most observations in the sample.

[9]Compared to that of *absolute* prices of agricultural goods, a plotted distribution of all *relative* prices across countries is much less informative because it lacks a consistent measure that enables comparisons between relative prices of *different pairs* of agricultural goods. Therefore, I focus on how the relative prices of the *same pair* of agricultural goods differ across countries.

differ substantially across countries. A larger than 200% difference in the relative prices of two agricultural goods is frequently observed. A comparison between Table 2.2 and 2.3 shows that the variability of the relative prices of agricultural goods is similar to that of the absolute prices of agricultural goods. That we observe relative prices differ considerably across countries suggests that there exist large cross-country differences in relative agricultural productivity.

Ideally, one would also like to compare the variation of agricultural prices in this section to that of prices of other tradeable goods such as manufactured goods. However, unlike agricultural prices, data on prices of a large sample of tradeable goods for a large sample of countries are hard to come by. A potential source of data is the International Comparison Program (ICP) from the World Bank. For example, in the latest round completed in 2005, the ICP has surveyed the prices of 129 goods in more than 100 countries. However, these data are not publicly available. I am currently in the process of requesting this data set from the World Bank office.

2.4.3 Estimating the Variation of Agricultural Productivity

This section describes the first step of the estimation procedure. In particular, the variation of agricultural productivity is inferred by estimating a structural equation that relates bilateral trade flows of agricultural goods to the ratio of two countries' agricultural prices, bilateral agricultural trade costs, and the target variable. Data on prices of individual agricultural goods and agricultural trade flows are used. This estimation strategy corresponds to the preferred method that yields the baseline value of the variation of productivity in manufacturing in Eaton and Kortum (2002).[10]

The estimated structural equation is derived from equation (2.5) by writing down the ratio of trade shares D^a_{ij} to D^a_{jj} as:

$$\frac{D^a_{ij}}{D^a_{jj}} = \left(\frac{P^a_j \tau^a_{ij}}{P^a_i}\right)^{-\frac{1}{\theta^a}} , \tag{2.7}$$

where D^a_{ij}/D^a_{jj} is the trade share of exporter j in country i, normalized by j's home trade share. P^a_i/P^a_j is the ratio of the prices of aggregate agricultural goods in country i and country j. θ^a is the variation of technology in agriculture, and τ^a_{ij} is the trade cost country j faces in exporting agricultural goods to country i.

Taking the log of equation (2.7) yields an expression that resembles a log-linear gravity equation:

$$\log\left(\frac{D^a_{ij}}{D^a_{jj}}\right) = -\frac{1}{\theta^a}\log\left(\frac{P^a_j \tau^a_{ij}}{P^a_i}\right) . \tag{2.8}$$

[10]Eaton and Kortum (2002) also consider two other methods to estimate the variation of productivity in manufacturing. The first method is based on the structural equation implied by this model that relates bilateral trade flows to wages and measures of country's average efficiency levels, such as national stocks of R&D and years of schooling. This approach is infeasible in my study as data on agricultural wages as well as country's R&D are not available for my sample countries. Another method Eaton and Kortum (2002) use is based on a structural equation similar to equation (2.7). However, as argued by the authors, this method tends to suffer from the "errors-in-variables" problem and overestimate the sectoral variation of productivity. As a result, I do not use this method.

Let χ_{ij} denote the ratio $\frac{P_j^a \tau_{ij}^a}{P_i^a}$, then the value of θ^a can be recovered by estimating the slope on $\log \chi_{ij}$ in equation (2.8).

Since bilateral trade flows are jointly determined by τ_{ij}^a and θ^a, I face an identification problem in estimating θ^a. To see this, suppose that the ratio of D_{ij}^a to D_{jj}^a is large, which suggests that agricultural trade intensity between i and j is relatively high. Given the observed price ratio $\frac{P_i^a}{P_j^a}$, this could be due to either high variation of agricultural productivity θ^a or low bilateral agricultural trade cost τ_{ij}^a (or the combination of the two). As a result, to estimate θ^a, one must first take a stand on the trade cost τ_{ij}^a.

As a measure on χ_{ij}, I follow Eaton and Kortum (2002) and use the model implication that, for each tradeable good, the ratio of its price in country i and country j ($p_i^a(x)/p_j^a(x)$) cannot exceed trade cost τ_{ij}^a. Therefore, one can approximate τ_{ij}^a by using the highest ratios of $p_i^a(x)/p_j^a(x)$ observed in the data.[11][12] As in Eaton and Kortum (2002), I use the mean of the ratios of prices of individual agricultural goods as the aggregate price ratio P_i^a/P_j^a.

In Figure 2.6, I plot the log of the ratio χ_{ij} against the log of normalized trade shares $\frac{D_{ij}^a}{D_{jj}^a}$. A point estimate of the variation of agricultural productivity θ^a is derived by estimating the slope on $\log(\chi_{ij})$, which is equal to $-\frac{1}{\theta^a}$

[11]In practice, as in Eaton and Kortum (2002), τ_{ij}^a is approximated by using the second highest observed value of the ratio $p_i^a(x)/p_j^a(x)$. The reason τ_{ij}^a is estimated by second-order statistics, rather than the maximum, is to reduce the potential impact of measurement error. Generally speaking, using the maximum of the observed price ratio yields higher bilateral trade costs. As a result, the estimated variation of productivity in agriculture tends to be smaller.

[12]Section 2.4.5 discusses the robustness of approximating trade costs τ_{ij}^a by maximum price differences in estimating θ^a.

(see equation (2.8)). Two methods are used in the estimation: OLS (without intercept) and method-of-moments. They yield similar results for θ^a: $\hat{\theta^a} = 0.24$ for OLS and $\hat{\theta^a} = 0.21$ for method-of-moments. I use 0.21 as the baseline value.

Using data on 19 OECD countries, Eaton-Kortum (2002) provide three estimates for the variation of technology in manufacturing: 0.08, 0.12, and 0.28. 0.12 is the estimate obtained using the method described in this section. It is also the preferred estimate and used as the baseline value in Eaton and Kortum (2002). Using the same method and based on data from 43 countries, Waugh (2009) provides an estimate of 0.18 for the variation of technology in manufacturing. Compared to these estimates for manufacturing, the estimate $\hat{\theta^a} = 0.21$ suggests that the variation of technology in agriculture is high.[13]

Lacking data on prices of individual manufactured goods from the sample countries, I do not estimate the variation of technology in the manufacturing sector. Given that the estimation in Waugh (2009) is based on a group of countries that share similar characteristics to the sample countries in this essay, I use Waugh's estimate $\hat{\theta^m} = 0.18$ as the variation of technology in manufacturing in my study.

[13]See Section 2.4.5 for a detailed discussion on the magnitude of θ^a and its implication on trade costs.

2.4.4 Estimating Trade Costs

After taking a stand on the magnitude of the variation of technology in the two tradeable sectors, I proceed to estimate trade costs. The estimation is based on the structural equation that defines bilateral trade shares (equation (2.5)):

$$\frac{D_{ij}^a}{D_{ii}^a} = \frac{(c_j^a \tau_{ij}^a)^{-1/\theta^a} \lambda_j^a}{(c_i^a)^{-1/\theta^a} \lambda_i^a} .$$

Rewriting in logs:

$$\log\left(\frac{D_{ij}^a}{D_{ii}^a}\right) = S_j^a - S_i^a - \frac{1}{\theta^a} \log \tau_{ij}^a , \tag{2.9}$$

where S_j^a is defined as

$$S_j^a = \log \lambda_j^a - \frac{1}{\theta^a} \log c_j^a . \tag{2.10}$$

S_j^a can be thought as country j's "competitiveness" in exporting agricultural goods, as higher S_j^a implies a larger share of country i's spending on agricultural goods from country j. Holding everything else constant, the more efficient country j is in producing agricultural goods (higher λ_j^a) the more likely country j exports agricultural goods to country i (larger D_{ij}^a). On the other hand, the higher the unit cost of producing agricultural goods in country j (higher c_j^a) the less likely country j exports agricultural goods to country i (smaller D_{ij}^a).

To model trade costs τ_{ij}^a, I turn to the gravity literature. A number of studies, such as Eaton and Kortum (2002), Anderson and van Wincoop (2004), and Waugh (2009), find that distance is the main impediment to bilateral trade flows. This also seems to hold true for agricultural trade. In Figure 2.7, the normalized trade share $\frac{D_{ij}^a}{D_{ii}^a}$ is plotted against bilateral distance. One can clearly see that a negative relationship exists between the two variables, with a correlation of -0.46.

Motivated by the observation in Figure 2.7, I follow the gravity literature and assume that

$$\log \tau_{ij}^a = d_k^a + b^a + l^a + \epsilon_{ij}^a \ , \tag{2.11}$$

where d_k^a $(k = 1, ..., 6)$ are the effects of distance on the trade costs of agricultural goods, and distance is divided in six intervals (in miles): [0,375); [375,750); [750,1500); [1500,3000); [3000,6000); and [6000,maximum).[14] b^a is effect of shared border, and l^a is effect of having a common language.

The estimation of the trade equation on manufactured goods follows the same procedure. Results of the OLS estimations on agricultural trade costs and manufacturing trade costs are included in Table 2.4.

The estimated values of the parameters in Table 2.4 all have the expected signs. Namely, distance increases trade costs, while shared border and shared language help to reduce trade costs. However, quantitatively, the effects of distance are much larger than those of shared border and shared language. For example, the effects of distance are such that it requires at least additional 1.89 units and up to additional 4.48 units of agricultural goods to ship one unit from one country to another. One the other hand, shared border and shared language decrease agricultural trade costs by about 0.1 unit and 0.09 unit of

[14]As in Eaton and Kortum (2002), the estimation of distance effects are based on discreet intervals of distance. As argued in Anderson and van Wincoop (2004), this is a flexible way to model distance effects and tends "to be more robust to specification error."

the traded agricultural goods. Similar to the case of agricultural trade costs, the effects of distance on increasing manufacturing trade costs are more than 10 times (from 0.89 units to 2.65 units of manufactured goods) larger compared to the effects of shared border (0.06 units) and shared language (0.05 units) on reducing trade costs.

From Table 2.4, one can see that trade costs on both tradeable goods are substantial. The estimated bilateral trade costs on agricultural goods range from 2.70 to 5.48, while those on manufactured goods range from 1.77 to 3.65. This means that it requires at least 2.70 and 1.77 units of agricultural and manufactured goods to ship one unit of them from one country to another. Moreover, the required units of goods can be as high as 5.48 and 3.65 for agricultural and manufactured goods.

Lastly, the results in Table 2.4 also indicate that bilateral trade costs on agricultural goods are at least twice as large as those on manufactured goods. Specifically, for a pair of countries, agricultural trade costs are at least 50% and up to 63% larger than manufacturing trade costs.

The Eaton-Kortum model predicts that all bilateral trade shares are nonzero. In practice, zero bilateral trade flows are frequently observed in the data. For the 46 sample countries, about 26% of bilateral agricultural trade are zero, while about 13% are zero for manufacturing trade. To avoid possible bias from the omission of zero trade flows, I also estimate the trade equations using the poisson pseudo-maximum-likelihood method proposed in Silva and Tenreyro

(2006). The results are included in Table 2.5. Compared to results in Table 2.4, one can see that OLS without zero trade tends to yield higher trade costs for both tradeable goods. However, quantitatively the differences, which range from 3% to 17%, are not in the order of magnitude. Results provided by the poisson pseudo-maximum-likelihood method still indicate substantial trade costs, with agricultural trade costs about twice as large as manufacturing trade costs.

2.4.5 Robustness and Discussion

The estimation results in Section 2.4.3 and 2.4.4 indicate that productivity variation is large in agriculture and that the low trade intensity in agricultural goods shown in Figure 2.1 is primarily due to high agricultural trade costs. In this section, I provide some discussions on the robustness of these findings.

It is worth emphasizing that estimations in this essay proceed sequentially and that the variation of agricultural productivity is determined *before* bilateral trade costs are estimated. This is important since the estimated value of the variation of agricultural productivity directly affects the values of the estimated trade costs. To see this, first consider the case that the estimated variation of agricultural productivity is large. This suggests that gains from agricultural trade are large and, as a result, countries should have a lot of incentives in trading agricultural goods with one another. The fact that we observe the contrary must necessarily mean that *high* agricultural costs are preventing them from doing so. On the other hand, if the estimated variation of agricultural productivity is sufficiently small, it suggests that the available gains from agricultural trade are small, which provides few incentives for countries to trade agricultural goods. In this case, agricultural trade costs can be *either* high *or* low.

In fact, quantitatively, values of the estimated agricultural trade costs are highly sensitive to the estimated variation of agricultural productivity θ^a. For example, setting the baseline value 0.21 for θ^a to 0.14 - a value used in Tombe (2011) - will lower the estimated agricultural trade costs by about 50%. On the other hand, if θ^a is set to 0.24, which is another estimate provided in Section 2.4.3, agricultural trade costs would be 22% higher.

Is the baseline value 0.21 a reliable estimate for θ^a? A concern one may have is whether the use of observed price ratios on individual agricultural goods, as in Section 2.4.3, is a robust way to approximate bilateral agricultural trade costs. It is important because these approximated agricultural trade costs are used in estimating the variation of agricultural productivity θ^a and, consequently, affect the values of the estimated agricultural trade costs τ^a_{ij}. To ensure its robustness, I first check how much the ratio χ_{ij} will differ between using observed price ratios and the estimated bilateral trade costs in Section 2.4.4. As Figure 2.8 shows, the majority of the two measures of χ_{ij} are clustered around the forty-five degree line. Moreover, when the variation of agricultural productivity is estimated using the estimated agricultural trade costs provided in Table 2.4, OLS yields 0.25 and method-of-moment yields 0.22 for θ^a.

Compared to the baseline results of 0.24 for OLS and 0.21 for method-of-moment, the new estimates of 0.25 and 0.22 are larger, but only slightly so - less than 5%.[15] These larger estimated θ^a have two implications. First, it implies larger variance for the distribution of agricultural productivity. Specifically, the standard deviation of the productivity distribution increases by 4.2% with the new estimated θ^a.[16] Second, the larger estimated θ^a will result in higher estimated trade costs on agricultural goods. When 0.25 and 0.22 are used in estimating trade costs, agricultural trade costs are on average 7.7% larger than those estimated using the baseline values of θ^a (0.21 and 0.24).[17] These results imply that, if anything, the baseline estimated agricultural trade costs reported in Section 2.4.4 are *understated*.

A direct comparison of the estimated θ^a in this essay to the existing literature is difficult since, to the best of my knowledge, no prior study has estimated the variation of productivity in agriculture using the Eaton-Kortum

[15] In contrast, the value used in Tombe (2011) - 0.14 - is about 50% smaller than my baseline value of the variation of agricultural productivity. This difference proves to be very important since the value of the estimated variation of agricultural productivity (θ^a) affects the estimated trade costs (τ_{ij}^a) non-linearly. In particular, a 5% larger θ^a leads to about 6% larger estimated trade costs, while a 17% smaller θ^a leads to about 30% smaller estimated trade costs.

[16] As in Eaton and Kortum (2002), the standard deviation is calculated as $(\pi\theta^a)/\sqrt{6}$.

[17] The fact that the new estimated θ^a and agricultural trade costs are higher implies that a fix point does not exist when one iterates on this process. This is because, given observed bilateral trade flows and price ratios ($\frac{D_{ij}^a}{D_{jj}^a}$ and $\frac{P_j^a}{P_i^a}$ in equation (2.7)), higher trade costs τ_{ij}^a will result in a higher estimated θ^a. When the higher θ^a is used in estimating τ_{ij}^a, it will in turn result in higher τ_{ij}^a. Therefore, both τ_{ij}^a and θ^a will just keep increasing if one iterates on this process. I am currently investigating this finding's implication on the consistency of the estimation strategy.

framework. Compared to existing estimates for manufacturing, which range from 0.08 to 0.28, my estimates of 0.21 and 0.24 suggest that the variation of technology in agriculture is high. These estimates, however, are consistent with the conjectures of other researchers. For example, in Eaton and Kortum (2002), the authors state that "(since) productivity in agriculture or mining is likely to be much more heterogeneous across countries, applying our model to trade in these goods could well deliver a much (higher) value of θ".

The estimated manufacturing trade costs in this essay fall in the middle of the range of recent estimates. Compared to Eaton and Kortum (2002), these estimates are roughly 100% higher than their baseline manufacturing trade costs. This is due to two reasons. First, Eaton and Kortum (2002) estimate trade costs using data from 19 OECD countries. Since rich countries trade more intensively with each other, it is not surprising that trade costs are lower in Eaton and Kortum (2002), as the sample countries in this essay include more poor countries with lower trade intensity.[18] Second, Eaton and Kortum (2002) use a lower value (0.12) for the heterogeneity of manufacturing productivity. Generally speaking, given observed bilateral trade shares, lower dispersion of productivity implies lower trade costs. If 0.12 were used (as in Eaton and Kortum (2002)), my estimates of manufacturing trade costs are about 40% higher than their baseline estimates.

[18] Of the 46 sample countries, 7 countries (15% of the sample countries) have a level of real GDP per capita that is less than 10% of the U.S.'s level. 13 countries (28% of the sample countries) have a level of real GDP per capita that is less than 20% of the U.S.'s level.

On the other hand, my estimates of manufacturing trade costs are about 60% lower than Waugh (2009). This is mainly because trade costs are allowed to be asymmetric in Waugh (2009). Specifically, in his study Waugh argues that rich countries systematically face lower trade costs than poor countries. As a result, the estimated impacts of distance, language and border on trade costs in Waugh (2009) are higher than the estimates provided in this essay since trade costs are symmetric and consequently represent more like averages for rich and poor countries.

Another finding in this essay is that agricultural trade costs are substantially larger than manufacturing trade costs. Although this essay is agnostic about the exact causes of the estimated trade costs, various direct measures do support larger trade costs on agricultural goods. Based on the GTAP data base, Figure 2.9 shows the ad valorem import tax rates for agricultural goods and manufacturing goods for a sample of 77 countries and regions. This measure of import tax rate includes a wide range of trade policies such as tariffs, quotas, and the like. One can clearly see that, for all sample countries, policy barriers on agricultural goods are substantially higher than those on manufactured goods. Moreover, as reported by Hummels (2001) and Hummels (2007), transportation costs on agricultural goods are on average about 50% higher than those on manufactured goods. This is mainly due to the low value-to-weight nature of agricultural products.

2.5 Conclusion

Why are agricultural goods not more intensively traded? Is it because trade costs are high on these goods or the gains from trading them are small? In this essay, based on structural gravity equations, I estimate both agricultural trade costs and the variation of technology in agriculture. I find that, relative to manufacturing trade, trade costs on agricultural goods are high and the variation of technology is large in agriculture. This finding suggests that there exist large potential gains from trade on agricultural goods. How large are these potential gains from trading agricultural goods? This is the question I turn to in the next chapter.

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Table 2.1: Summary statistics of absolute price differences of *all* agricultural goods

	Mean	Max	Mean	Max / Min	Standard Deviation	Within One Standard Deviation	Within Two Standard Deviations	Within Three Standard Deviations	
	1.00	38.82	2.56	38.82	2.59	83.7%	93.6%	97.0%	
	Within $[1, 2.5]$	Within $(2.5, 7.5]$	Within $(7.5, 12.5]$	Within $(12.5, 17.5]$	Within $(17.5, 22.5]$	Within $(22.5, 27.5]$	Within $(27.5, 32.5]$	Within $(32.5, 37.5]$	Within $(37.5, 40]$
Frequency (total 50380)	35942 (71.34%)	12272 (24.36%)	1523 (3.02%)	381 (0.76%)	144 (0.29%)	64 (0.13%)	30 (0.06%)	19 (0.04%)	5 (0.01%)

Table 2.2: Summary statistics of absolute prices of eight agricultural goods

Agricultural Good	Mean	Max	Mean	Max / Min	Standard Deviation	Within One Standard Deviation	Within Two Standard Deviations	Within Three Standard Deviations
Chicken	1553	3162	833	3.80	546	77%	93%	100%
Sheep	3211	8096	434	18.64	1549	72%	98%	98%
Milk	330	795	171	4.66	122.34	83%	95%	98%
Tomato	547	2039	110	18.57	437	85%	95%	98%
Cabbage	247	898	58	15.61	163	83%	98%	98%
Potato	227	531	44	12.18	132	66%	92%	100%
Apple	473	1743	74	23.72	333	84%	97%	97%
Banana	459	1301	126	10.29	336	79%	95%	100%

Table 2.3: Summary statistics of relative prices of five pairs of agricultural goods

Pair	Mean	Max	Mean	Max / Min	Standard Deviation	Within One Standard Deviation	Within Two Standard Deviations	Within Three Standard Deviations
Wheat / Rice	0.71	1.37	0.28	4.86	0.28	73%	96%	100%
Sheep / Chicken	0.62	3.21	0.23	13.82	0.49	93%	98%	98%
Tomato / Cabbage	2.60	10.0	0.38	26.08	1.95	79%	95%	97%
Apple / Banana	1.08	3.57	0.26	13.49	0.99	82%	91%	100%
Milk / Potato	1.91	4.76	0.44	10.88	1.15	72%	95%	100%

Table 2.4: Geographic barriers on tradeable goods

	Estimates		Std. Err.		% on Costs	
Variables	Ag.	Man.	Ag.	Man.	Ag.	Man.
Distance [0,375)	-5.05	-3.55	0.21	0.23	189	89
Distance [375,750)	-5.86	-4.15	0.13	0.14	242	111
Distance [750,1500)	-6.58	-4.86	0.10	0.10	298	140
Distance [1500,3000)	-7.44	-5.92	0.12	0.12	377	190
Distance [3000,6000)	-7.86	-6.56	0.05	0.06	421	226
Distance [6000,max)	-8.10	-7.20	0.06	0.06	448	265
Shared border	0.50	0.36	0.10	0.11	-10.0	-6.27
Shared language	0.45	0.30	0.18	0.20	-9.07	-5.26

Summary Statistics				
	No. Obs	TSS	SSR	σ_ϵ^2
OLS on Ag.	1666	95736	2699	1.68
OLS on Man	1884	78820	3709	2.03

Table 2.5: Geographic barriers on tradeable goods accounting for zero trade

	Estimates		Std. Err.		% on Costs	
Variables	Ag.	Man.	Ag.	Man.	Ag.	Man.
Distance [0,375)	-4.45	-3.26	0.16	0.13	155	98
Distance [375,750)	-5.34	-3.91	0.10	0.08	207	127
Distance [750,1500)	-6.05	-4.57	0.10	0.08	256	161
Distance [1500,3000)	-6.80	-5.14	0.12	0.12	317	194
Distance [3000,6000)	-7.62	-5.89	0.07	0.07	395	244
Distance [6000,max)	-7.79	-6.61	0.09	0.10	413	300
Shared border	0.05	0.38	0.15	0.12	-1.04	-6.27
Shared language	0.59	0.27	0.14	0.13	-11.65	-5.51
Summary Statistics						
	No. Obs	Log pseudolikelihood	Wald chi2(55)	Prob > chi2		
Poisson Regression on Ag.	2256	-25.57	38452	0.00		
Poisson Regression on Man	2256	-108.03	26817	0.00		

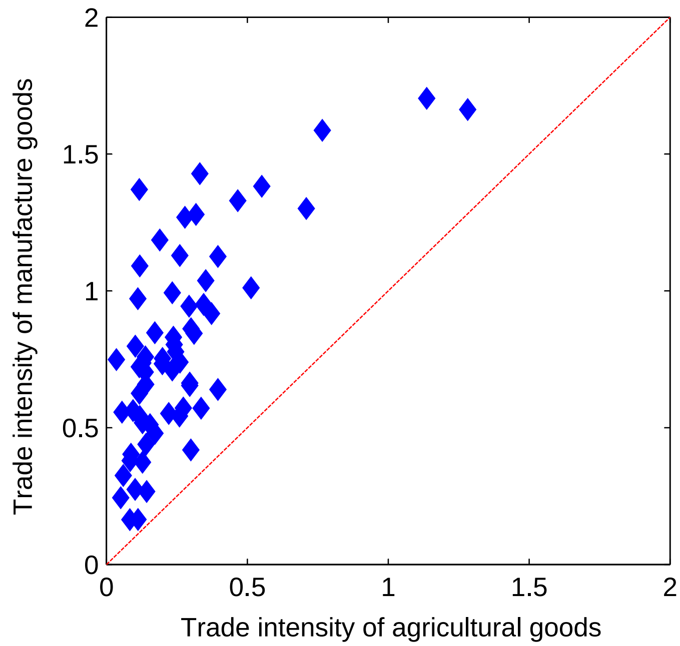

Figure 2.1: Trade intensity of agricultural and manufactured goods

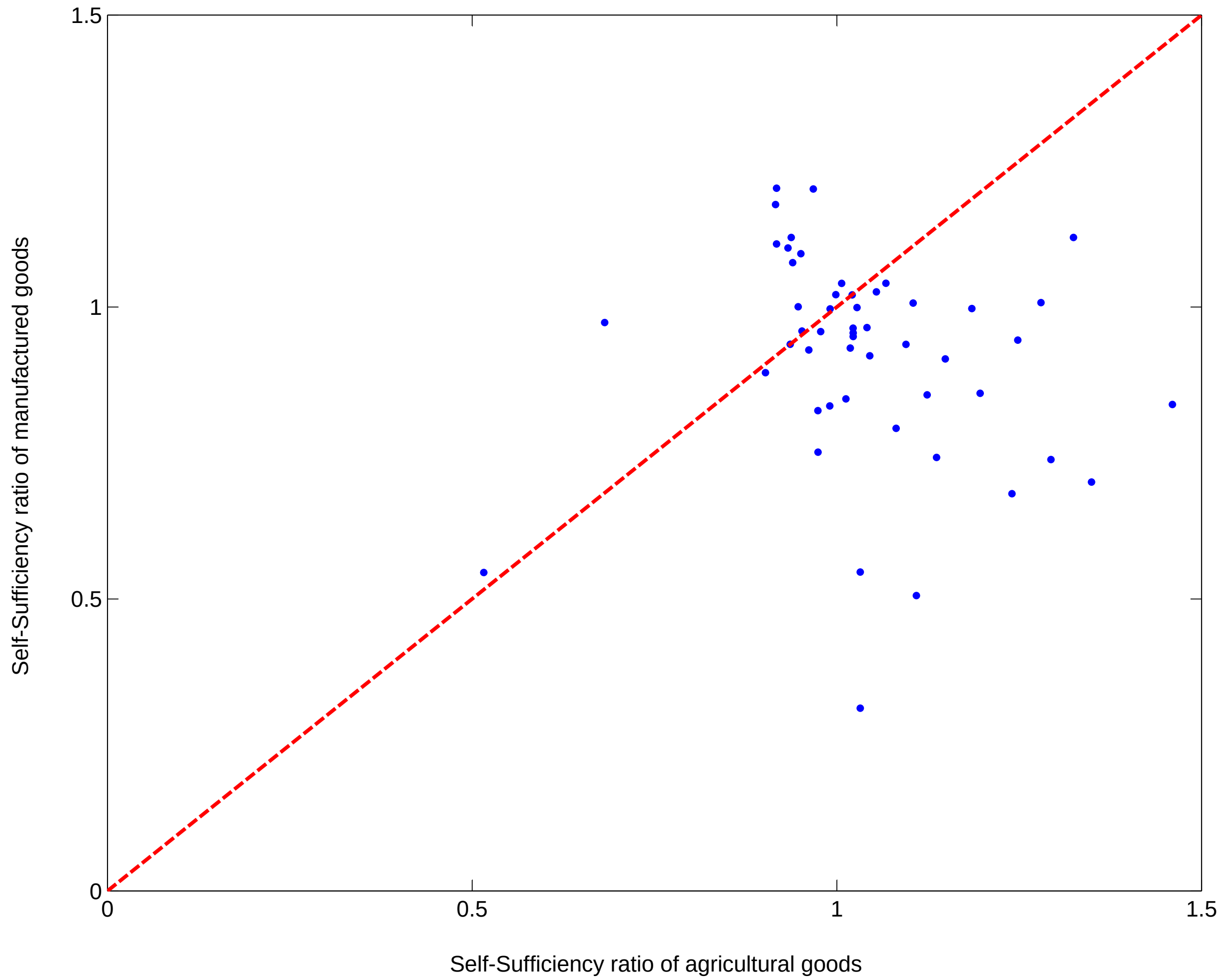

Figure 2.2: Self-sufficiency ratio of agricultural and manufactured goods

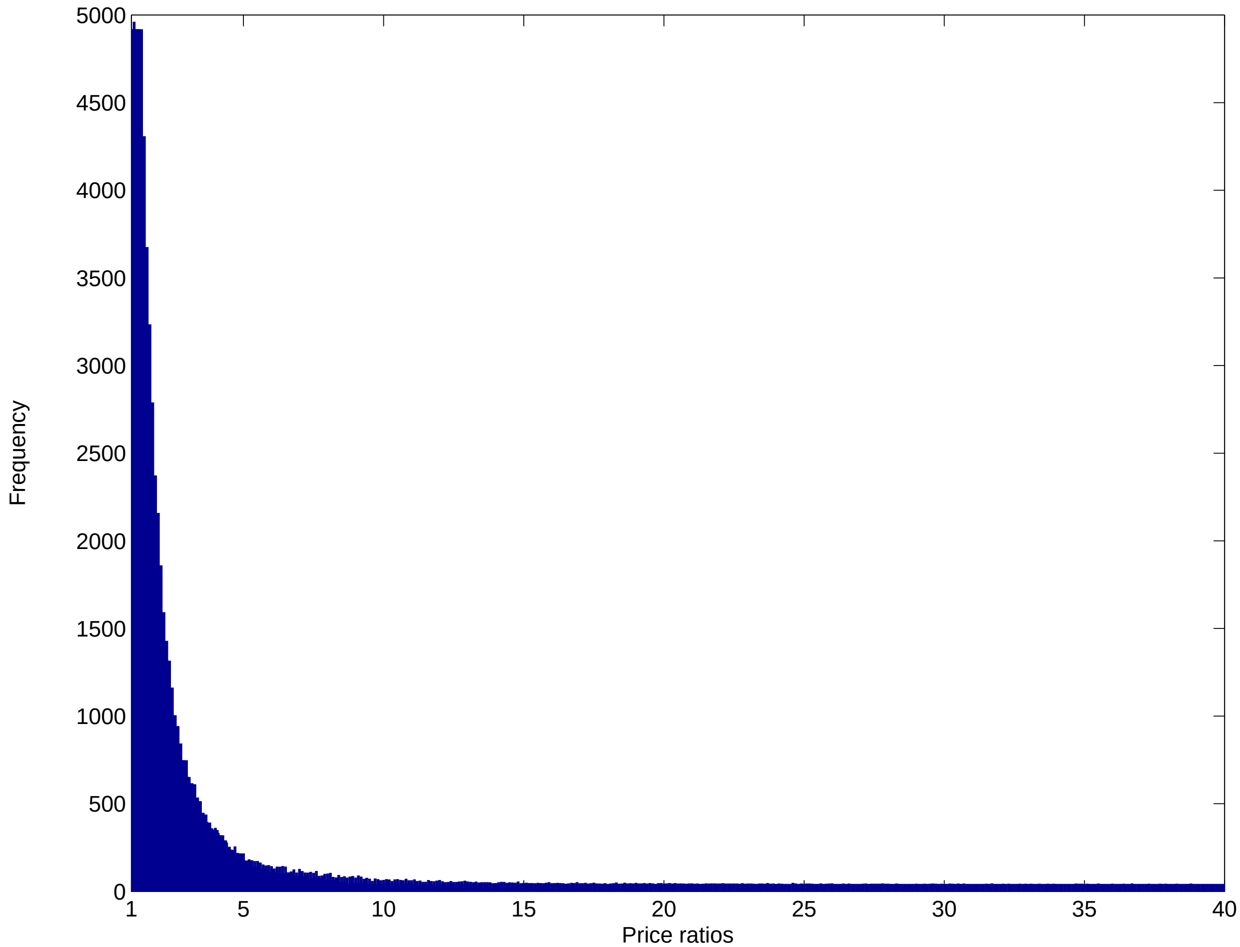

Figure 2.3: Price difference of the same agricultural goods across countries

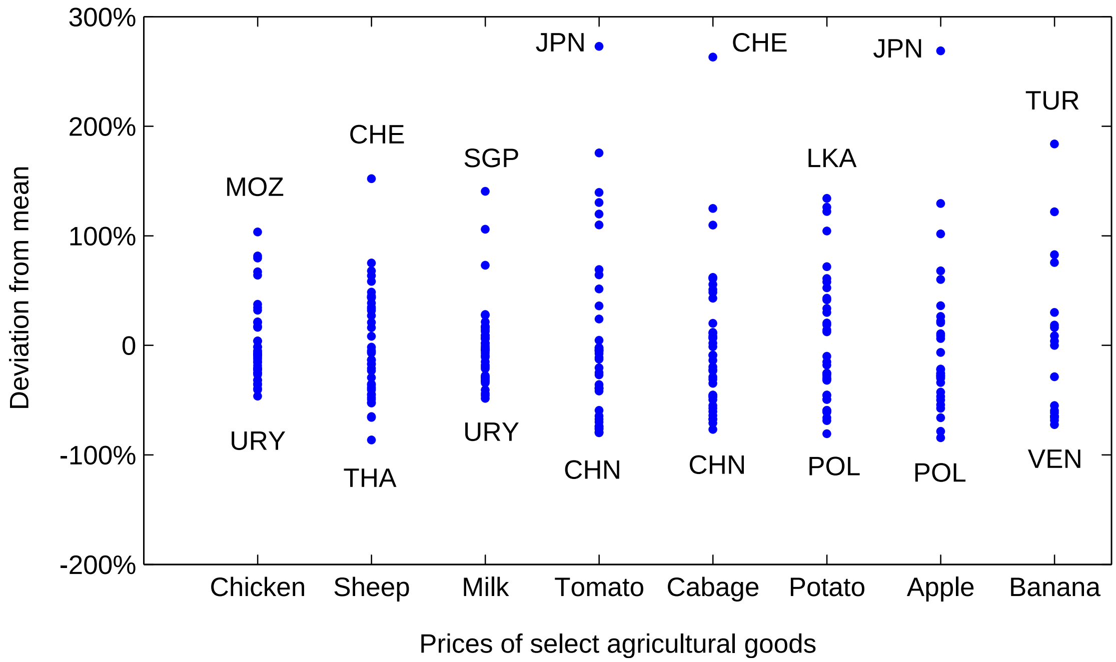

Figure 2.4: Cross-country price dispersion of agricultural goods

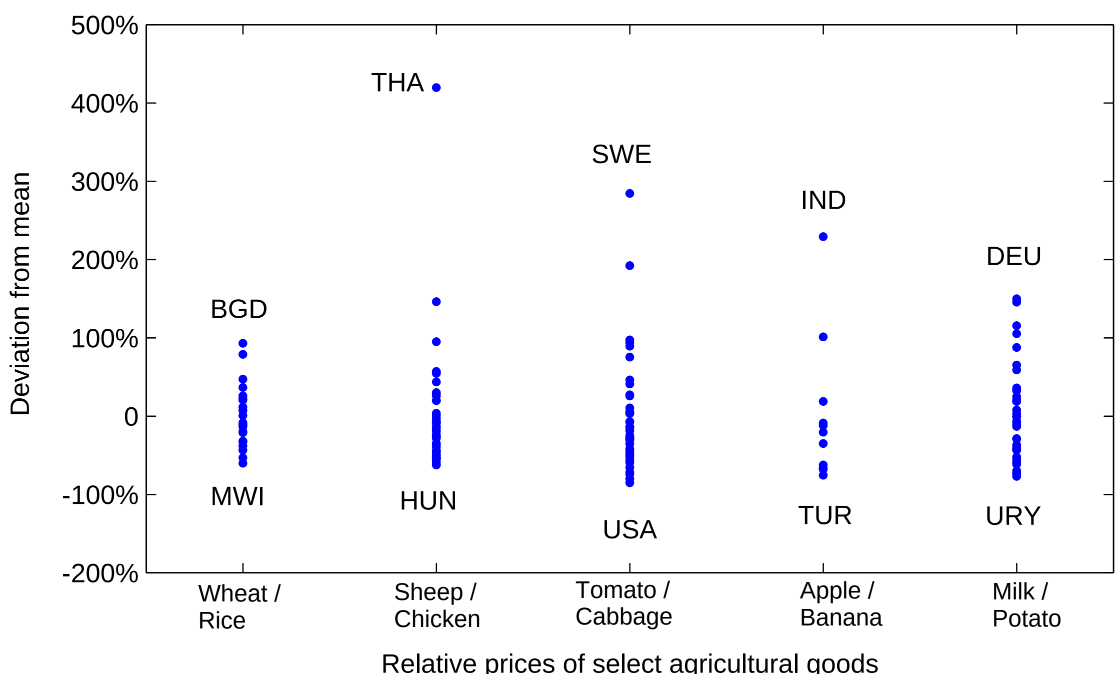

Figure 2.5: Dispersion of relative prices of select pairs of agricultural goods

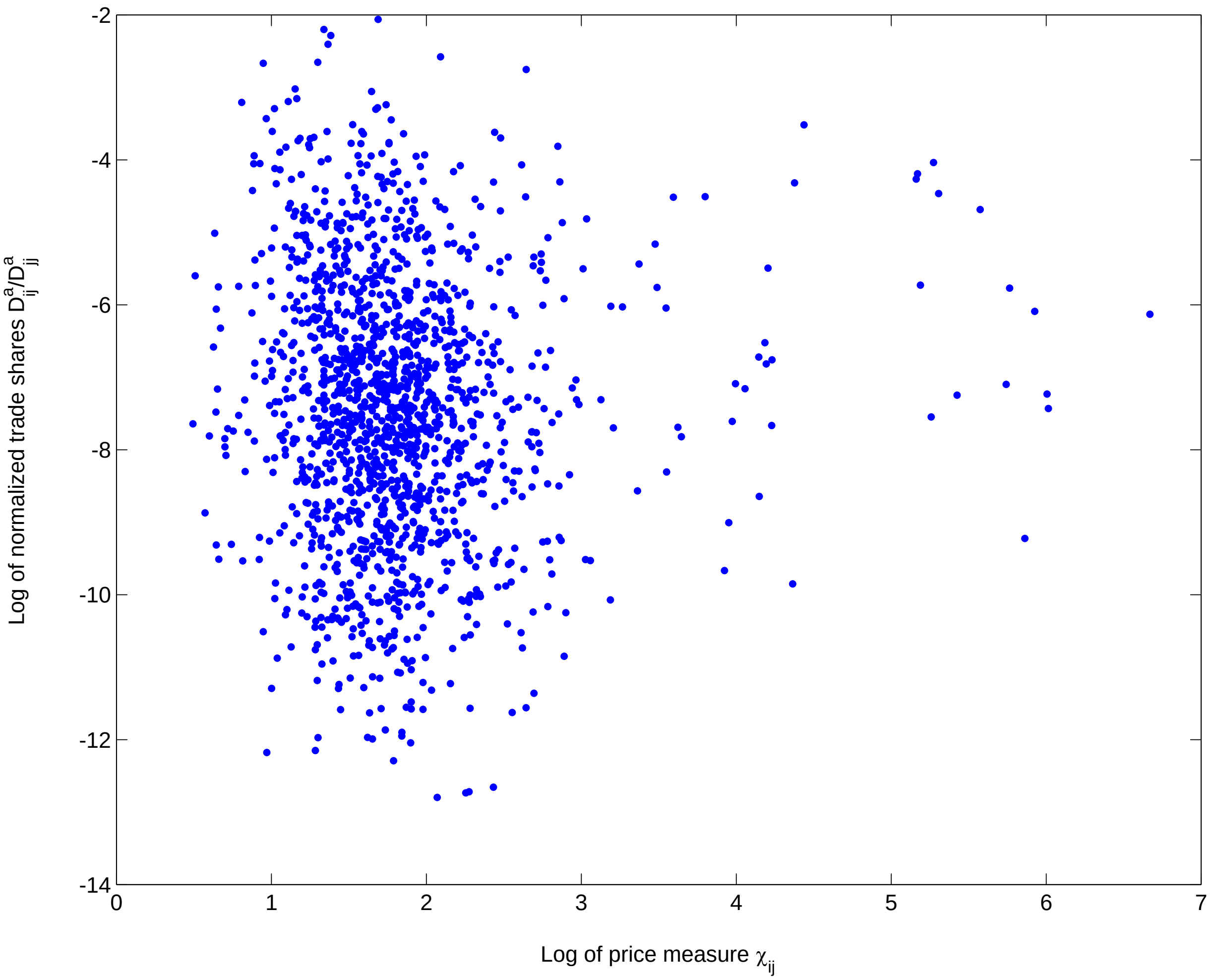

Figure 2.6: Normalized trade shares against price measure

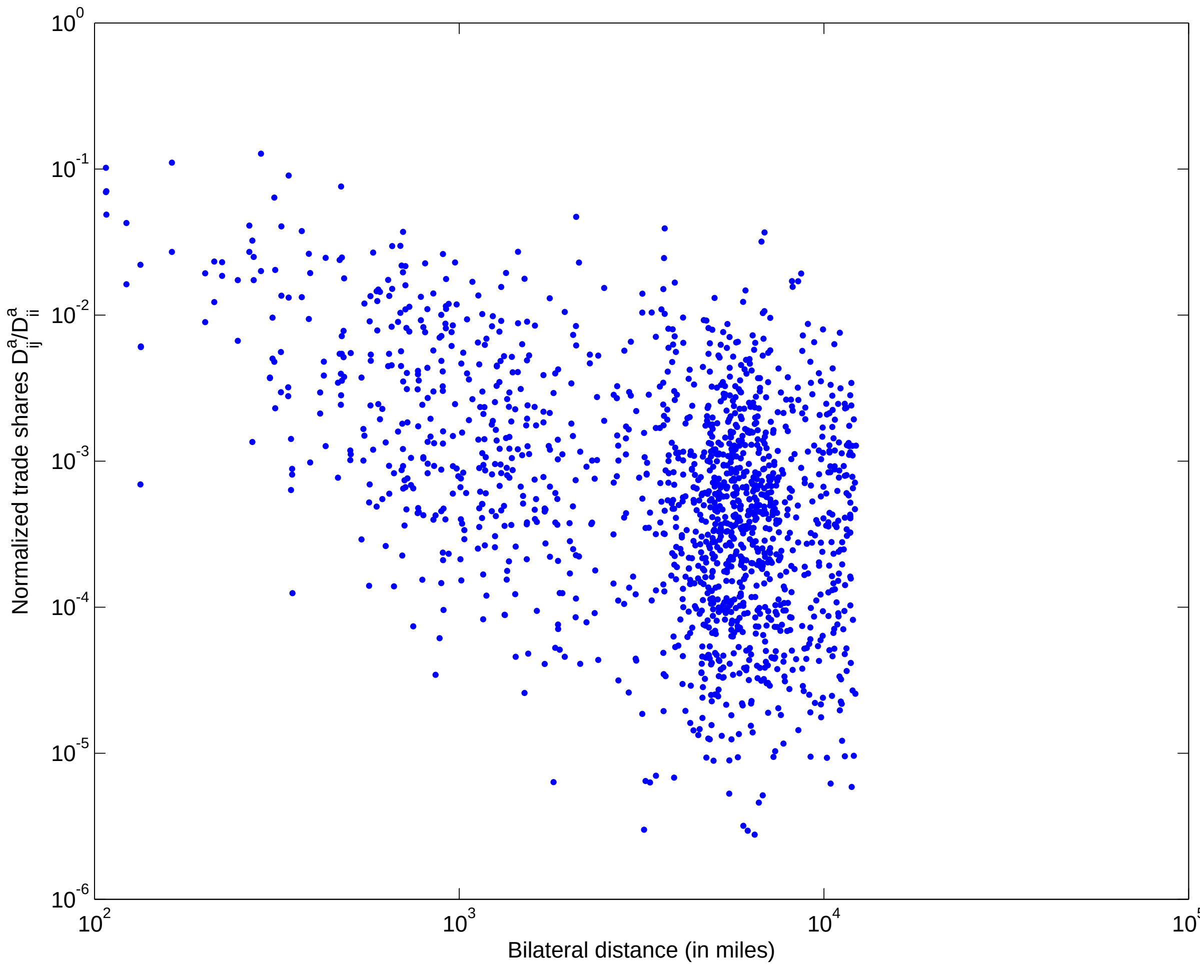

Figure 2.7: Normalized trade shares against bilateral distance

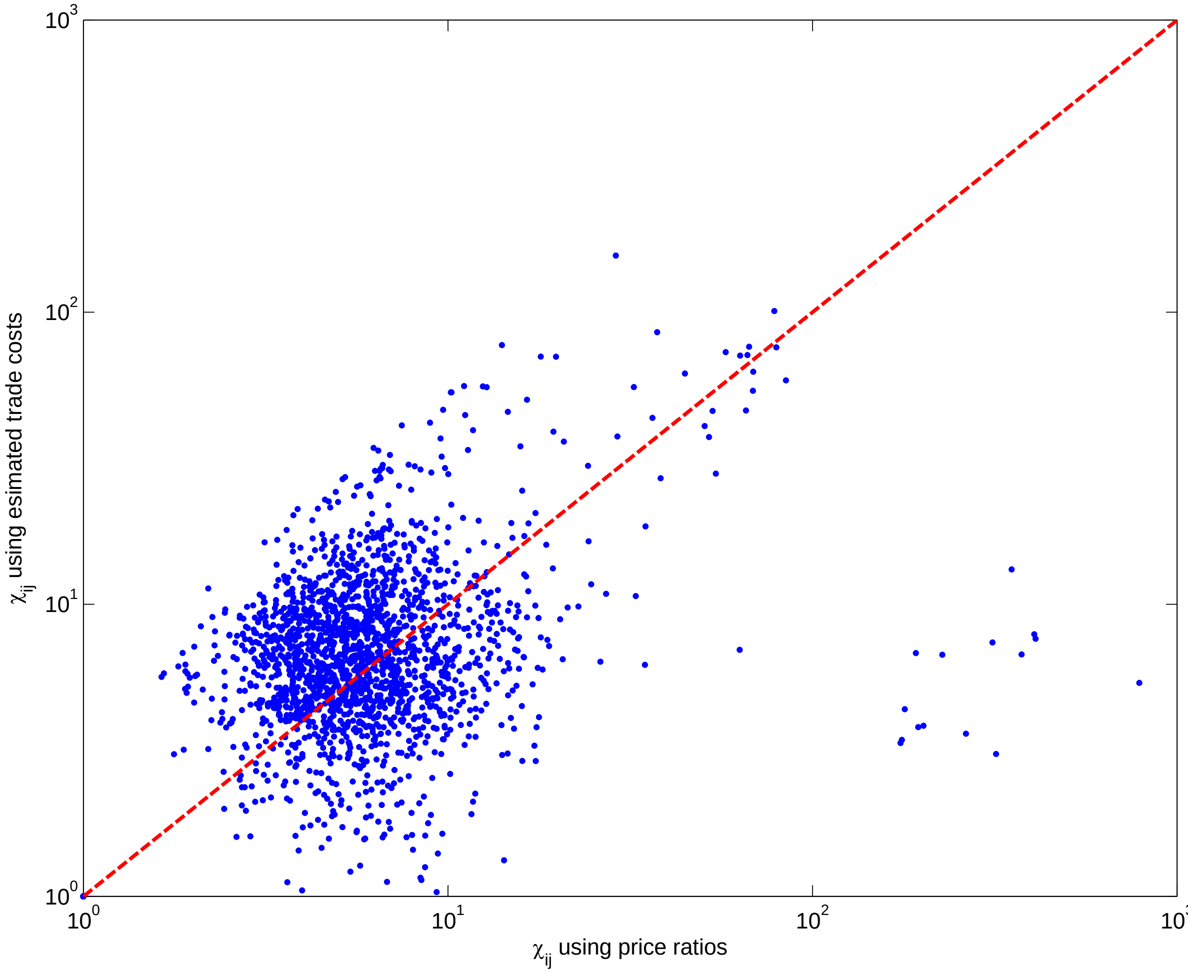

Figure 2.8: Robustness of using price ratios to approximate trade costs

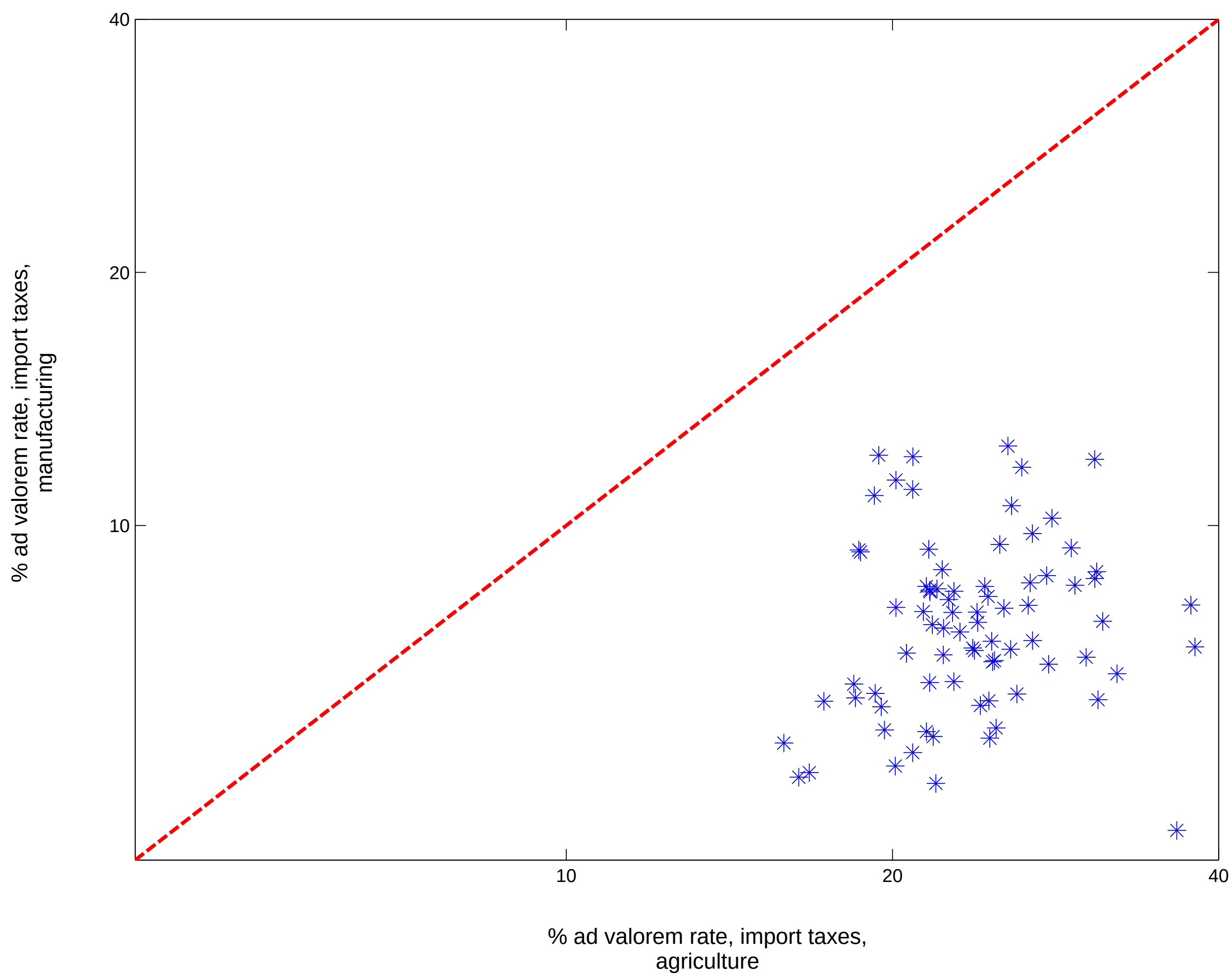

Figure 2.9: Ad valorem import tax rate, by source

Chapter 3

Gains from Trade and the Food Problem

3.1 Introduction

According to the "food problem" hypothesis, many countries are poor because they must devote large fractions of productive resources in the unproductive agriculture sector to satisfy subsistence needs for food. Two empirical observations are frequently cited in support of the food problem. First, in poor countries most workers are employed in agriculture, while in rich countries the agricultural employment share is very small. Moreover, not only do poor countries have low agricultural productivity, agriculture also tends to be the least productive sector in these economies. As a result, poor countries' income levels suffer from a large labor share in the relatively unproductive agriculture sector.

The theory of comparative advantage suggests that international trade can be a solution to the food problem. By specializing in its comparative advantage goods, a country faced with the food problem could satisfy subsistence needs while reallocating labor from agriculture to the more productive non-agriculture sector. However, despite the potential for trade to alleviate the food problem, trade intensity of agricultural goods is low. Moreover, the absolute and relative prices of agricultural goods vary substantially across countries, suggesting that trade barriers on agricultural goods are high. The combination of low trade intensity and high trade barriers implies large unrealized gains from agricultural trade. Because of the food problem, these forgone gains can be substantial for poor countries.

To measure these potential gains from trade, this essay asks the following question: In the presence of the food problem, how large are the gains from lowering trade costs? To answer this question, I extend the multi-country Ricardian trade model developed in Eaton and Kortum (2002). To capture the key features of the food problem, a tradeable agriculture sector and minimum consumption of agricultural goods (non-homothetic utility) are added to the Eaton and Kortum model. The third key addition to the Eaton and Kortum model is home production in agriculture, which accounts for the fact that a significant portion of poor countries' agricultural labor engages in subsistence farming. For a sample of 46 countries, the model is calibrated to observed bilateral trade flows, sectoral employment shares, and relative real GDP per capita. With the quantified model, I perform counterfactual exercises to evaluate the effects of lowering trade costs on countries' income levels.

In the model, international trade helps poor countries overcome the food problem in two ways. First, by trading agricultural goods with the rest of the world, each poor country specializes in a set of agricultural products that it is relatively good at producing and exchanges these agricultural goods for goods that they are relatively bad at producing. This *intra-sectoral* trade facilitates more efficient agricultural production in poor countries, and it is governed by each country's comparative advantage *within* agriculture. Second, given that they are generally more productive in manufacturing than in agriculture, poor countries become net importers of agricultural goods and net exporters of manufactured goods. This *inter-sectoral* trade allows poor countries to allocate their productive resources to the relatively more productive manufacturing sector, and it is governed by each country's comparative advantage *between* agriculture and manufacturing.

The economy in each country has three sectors: tradeable agriculture and manufacturing sectors and non-tradeable service sector. In each tradeable sector there is a continuum of goods. These tradeable goods are subject to sector-specific "iceberg" trade costs, and firms in each country purchase them from producers who offer the lowest price, after accounting for trade costs. Workers in the model consume the goods produced by all three sectors, but there is a minimum consumption level for agricultural goods. Workers can move across sectors, but not across countries. Moreover, workers in the agriculture sector also have access to the home production technology, which is identical across countries and only produces non-tradeable agricultural goods for final consumption.

Data from a sample of 46 countries are used to calibrate the model in two steps. First, with previously estimated trade costs and the heterogeneity of agricultural productivity, preference parameters are calibrated to observed sectoral employment shares.[1] Second, parameters of sectoral efficiency are inferred from estimates from trade equations as well as country's relative real GDP per capita.

To measure potential gains from trade in the presence of the food problem, the quantified model is used to examine the effects of lowering trade costs. In the first counterfactual, all trade costs are set to zero, which gives the maximal potential gains from trade. I find that gains from frictionless trade are substantial for all countries, with an average increase of 166% in real GDP per capita. However, these gains are much larger for poor countries with the food problem. Sorting according to baseline agricultural employment shares, countries in the bottom quartile (high agricultural employment shares) on average enjoy more than 330% increases in real GDP per capita, while countries in the top quartile (low agricultural employment shares) on average experience about 70% increases in real GDP per capita.

[1] Trade Costs and the variation of technology in agriculture are estimated in the previous chapter *"Why Are Agricultural Goods Not Traded More Intensively: High Trade Costs or Low Productivity Variation?"*.

What drives poor countries' much larger gains from trade is the substantial reallocation of labor from the unproductive agriculture sector to the more productive non-agriculture sectors. The elimination of trade costs enables poor countries' reallocation of agricultural workers in two ways. First, zero trade costs on agricultural goods leads to more than eight-fold increase in world output per worker in agriculture. This substantial increase in world agricultural productivity combined with the low income elasticity of agricultural goods creates large amount of surplus labor in agriculture, most of which reside in poor countries. Second, zero trade costs on both tradeable goods enable poor countries to become large net importers of agricultural goods and net exporters of manufactured goods. As poor countries no longer need to devote large fractions of workers in the relatively unproductive agriculture sector to satisfy subsistence, they experience significant increases in real income.

While being agnostic about the causes of the estimated trade costs, I find that for poor countries significant gains from trade are present with plausible reductions on agricultural trade costs. For instance, a 20% reduction on agricultural trade costs, which leaves them about 60% higher than current manufacturing trade costs, would deliver a roughly 10% average increase in real GDP per capita for countries in the bottom quartile (high agricultural employment shares). In contrast, the same percentage reduction on manufacturing trade costs delivers less than 2% average increase in real income. When agricultural trade costs are lowered to equal to the level of baseline manufacturing trade costs (about 45% reduction), the average increase in real GDP per capita is about 22%. These gains from trade are substantial, considering that in the past ten years the average annual growth rate in real income per capita was 2.5% for these countries.

To compare gains from trade in this essay to those in the recent studies of the Eaton-Kortum trade model, I study a variant of the model in which subsistence needs and home production of agricultural goods are dropped. In this framework, countries differ little in their sectoral compositions, and labor reallocation only occurs within the tradeable sector. This formulation of the world economy closely resembles the models used in Alvarez and Lucas (2007) and Waugh (2009). It also allows to me to isolate the quantitative importance of subsistence and home production, which are the two key features of my model.

In contrast to Alvarez and Lucas (2007), who find that gains from frictionless trade are relatively small (with a maximum of 6% in welfare gains), gains from trade in this essay are substantial (with a maximum of 667% in real GDP increase) and much larger for poor countries. By evaluating gains from trade in the framework that resembles Alvarez and Lucas (2007), I find that potential gains from trade are consistently underestimated for poor countries with the food problem. For instance, for countries in the bottom quartile (high baseline agricultural employment shares), the average increase in real GDP per capita is more than 330% in this essay's benchmark model, while it is about 160% in the framework that resembles Alvarez and Lucas (2007). In other words, gains from trade are underestimated by as much as 50%.

Similar to Waugh (2009), I also find that cross-country income differences decrease significantly in frictionless trade, but with a very different mechanism. While the reduction in Waugh (2009) is 42%, in this essay the variance of the log of real income per capita decreases by 43% after all trade costs are eliminated. However, unlike Waugh (2009), in this essay poor countries' large gains from trade are not predicated on having systematically higher trade costs than rich countries. Instead, it is because free trade enables poor countries to reallocate large fractions of their labor from the relatively unproductive agriculture sector to other sectors. In a model without subsistence and home production - a framework that resembles Waugh (2009) with *symmetric* trade costs - the variance of the log of real income per capita decreases by 16% in frictionless trade. This is about one-third of the reduction in frictionless trade when subsistence and home production are present.

Another related paper is Tombe (2011), which studies how poor countries' lack of agricultural imports contributes to cross-country differences in income and aggregate productivity levels. Similar to this essay, it is also based on an Eaton-Kortum trade model that features a tradeable agriculture sector and subsistence needs of agricultural goods. This essay differs from Tombe (2011) in two ways. First, the two studies approach the observed income gap between agriculture and non-agriculture in poor countries very differently. In particular, unlike this essay where the lower income in agriculture is largely explained by the existence of home production of agricultural goods, Tombe (2011) argues that there exist significant distortions to poor countries' labor market that depress agricultural income in those countries. Second, the two studies differ in their stands on the degree of variation of agricultural productivity. In particular, this essay argues that the variation of productivity in agriculture is much (50%) larger than that in Tombe (2011). This results in substantially larger gains from lowering agricultural trade costs in this essay.

This essay is closely related to the recent development in multi-country Ricardian trade literature. Subsequent to the seminal paper Eaton and Kortum (2002), a number of studies, including Alvarez and Lucas (2007), Waugh (2009), and Fieler (2010), have applied the Eaton-Kortum model to analyze trade patterns and gains from trade in a multi-country environment. This essay is also related to studies that utilize computable general equilibrium (CGE) models to analyze issues pertaining to agriculture and trade. Blake et al (1999), van der Mensbrugghe and Beghin (2004), Anderson et al (2005), and Decreux and Valin (2007) are studies that apply CGE models to examine how trade in agricultural goods impacts a country's agricultural development and its income level.

This essay is related to a large literature on agriculture and economic development. Recent studies (Gollin et al (2007), Restuccia et al (2008), and Lagakos and Waugh (2010)) focus on how a country's level of agricultural development and frictions within the agriculture sector impact its level of income and growth experience. Another related literature is the literature of structural transformation. Studies in this literature, for instance, Laitner (2000), Caselli and Coleman (2001), Duarte and Restuccia (2010) have examined the role of sectoral changes in a country's overall economic performance.

The rest of the essay is organized as follows. Section 3.2 presents four empirical facts that motivate this essay. Section 3.3 describes the model. Section 3.4 explains the calibration of the model and presents several key findings from this exercise. Section 3.5 performs a number of counterfactual exercises. Section 3.6 concludes.

3.2 Four Empirical Facts

In this section I document four key empirical facts, the last two of which are first established in Chapter 2. First, in poor countries, large fractions of employment are in agriculture. Second, the relative labor productivity of agriculture to non-agriculture is lower in poor countries than in rich countries. Third, trade intensity of agricultural goods is low. Last, both absolute and relative prices of individual agricultural goods differ substantially across countries.

These four facts have important implications for the magnitude and distribution of gains from trade. That observed trade intensity of agricultural goods is low despite the large variation of relative prices of agricultural goods suggests that large potential gains exist in agricultural trade. Given that they allocate large fractions of labor in the relatively unproductive agriculture sector, these gains can be much higher and quantitatively important for poor countries.

Fact 1: Cross-Country Differences in Agricultural Employment Share

Agricultural employment share differs systematically with a country's income level. Using 1997 data on sectoral employment shares from the World Bank's World Development Indicators (WDI) and real GDP per capita from the Penn World Tables (PWT 6.3), Figure 3.1 shows that poor countries have significantly larger fractions of workers in agriculture than rich countries. Of the 84 countries surveyed in Figure 3.1, the poorest five countries on average devote 58% of their workforce to agriculture, as compared to less than 4% for the richest five countries.

Fact 2: Cross-Country Differences in Relative Productivity of Agriculture to Non-agriculture

Not only do poor countries systematically allocate more labor in agriculture, the relative productivity of agriculture to non-agriculture also tends to be lower in poor countries than in rich countries. Using data on agricultural employment share and GDP share (from WDI), I calculate the ratio of GDP per worker in non-agriculture to GDP per worker in agriculture, which is then plotted against real GDP per capita (from PWT 6.3) in Figure 3.2. It shows that, while output per worker in agriculture is generally smaller than output per worker in non-agriculture (ratio over one), this productivity gap tends to be larger in poor countries.

The facts depicted in Figure 3.1 and 3.2 have long been noted by economists. They have led to a large number of studies that examine the impact of agricultural development on cross-country income differences and economic growth (Shultz (1953), Gollin et al (2004), Gollin et al (2007), and Resuccia et al (2008)). A common theme in these studies is that, because of subsistence needs, poor countries must devote large fractions of productive resources in the relatively unproductive agriculture sector. This is commonly referred to as the "food problem".

Fact 3: Low Trade Intensity of Agricultural Goods

Agricultural goods are not intensively traded. Drawing on data on trade flows and productions of both manufactured and agricultural goods, Section 2.2 in Chapter 2 discusses three key empirical observations in support of the low trade intensity of agricultural goods.

First, despite that world manufacturing GDP is larger than world agricultural GDP, total volume of manufacturing trade is even larger than that of agricultural trade. In particular, in 1997, while world manufacturing GDP was less than 5 times of world agricultural GDP, the value of manufacturing trade was more than 9 times of that of agricultural trade. This must necessarily mean that, not only agricultural goods are traded less than manufactured goods, they are also traded *less intensively* than manufactured goods.

Second, for a sample of 48 countries, trade intensity of agricultural goods is consistently lower than that of manufactured goods. This empirical observation is documented in Figure 2.1. Measured as the ratio of the sum of total exports and imports to gross production, agricultural goods are traded less intensively than manufactured goods for *all* 48 countries, which cover a wide range of income levels. Moreover, for more than 80% of the sample countries, trade intensity of agricultural goods is less than half of that of manufactured goods.

Last, relative to that of manufacturing production, the domestic share of agricultural production is higher for a large number countries. In particular, for the 48 countries surveyed earlier, 33 (about 70% of the sample) have higher domestic share of agricultural production than that of manufacturing production. This empirical observation is documented in Figure 2.2.

In summary, as established in Section 2.2, the above three empirical observations show that, relative to manufactured goods, agricultural goods are traded less intensively.

Fact 4: Prices of Agricultural Goods

Why are agricultural goods not traded more intensively? There are two possible explanations: i) high trade costs; ii) small dispersion of relative productivity in agriculture. To help determine the relative roles of these two factors, Section 2.4.2 in Chapter 2 discusses how the absolute and relative prices of agricultural goods differ across countries.

Documented in Figure 2.3 and Table 2.1, the prices of agricultural goods differ substantially across countries. Large price differences of the same agricultural good are frequently observed. For example, about 4.3% of the sample have a price difference that is equal or larger than 650%. Moreover, as Figure 2.4 shows, the observation of large price differences applies to a wide range of agricultural goods and a large number of countries.

To examine the dispersion of productivity in agriculture, Section 2.4.2 also discusses how relative prices of agricultural goods differ across countries. As Figure 2.5 and Table 2.3 show, similar to absolute price differences, the relative prices of agricultural goods also differ substantially across countries.

That we observe large cross-country differences in the *absolute* prices of agricultural goods suggests that there exist large trade barriers on agricultural goods. Moreover, the also large differences in the *relative* prices of agricultural goods suggests that the variation of agricultural productivity is large. As it governs the degree of comparative advantage in trade, this in turn suggests that gains from trading agricultural goods are large. Given the current low trade intensity of agricultural goods and the high agricultural trade barriers, these gains from agricultural trade are largely unrealized.

3.3 The Model

The model builds on the multi-country Ricardian trade model in Eaton and Kortum (2002).[2] Three extensions are made. In order to consider agricultural development and subsistence, an explicit tradeable agriculture sector and minimum consumption of agricultural goods are added to the Eaton and Kortum model. Moreover, to account for the fact that a significant portion of poor countries' labor in agriculture engages in subsistence farming, home production technology is introduced into the production of agricultural goods.

In the model, the world economy consists of n countries. Each country i has a measure of L_i workers. Labor is mobile across sectors, but immobile across countries. Within each country there are three sectors: agriculture, manufacturing, and service. All variables below are normalized relative to country i's number of workers L_i.

[2]The production side of the model is almost identical to Chapter 2. However, unlike the partial equilibrium model in Chapter 2, the current model also includes the demand side and is a general equilibrium model.

3.3.1 Production

Tradeable Sectors

Within country i, there are two tradeable sectors: agriculture (a) and manufacturing (m). A continuum of intermediate goods, indexed by $x^a, x^m \in [0,1]$, exist in each tradeable sector. The productions of intermediate agricultural good $q_i^a(x^a)$ and intermediate manufactured good $q_i^m(x^m)$ are given by:

$$\begin{aligned} q_i^a(x^a) &= z_i(x^a)^{-\theta^a}[s_i^a(x^a)]^{\gamma^a}[Q_i^a(x^a)]^{1-\gamma^a}, \\ q_i^m(x^m) &= z_i(x^m)^{-\theta^m}[s_i^m(x^m)]^{\gamma^m}[Q_i^m(x^m)]^{1-\gamma^m}, \end{aligned}$$

where $z(x^a)^{-\theta^a}$ and $z(x^m)^{-\theta^m}$ are the productivities used in producing goods x^a and x^m. $s_i^a(x^a)$ and $s_i^m(x^m)$ denote shares of labor used to produce these two goods. Similarly, $Q_i^a(x^a)$ and $Q_i^m(x^m)$ are the aggregate agricultural goods and manufactured goods used in producing x^a and x^m. It is assumed that $0 < \gamma^a, \gamma^m < 1$, and θ^a and θ^m are the same across countries, i.e. both parameters are sector-specific but not country-specific.

Aggregate agricultural goods and aggregate manufactured goods are simple aggregates of intermediate goods and used as both intermediate inputs and final consumption goods:

$$\begin{aligned} Q_i^a &= \left[\int_0^\infty q_i^a(x^a)^{1-1/\eta}\phi(x^a)dx^a\right]^{\eta/(\eta-1)}, \\ Q_i^m &= \left[\int_0^\infty q_i^m(x^m)^{1-1/\eta}\phi(x^m)dx^m\right]^{\eta/(\eta-1)}. \end{aligned}$$

As in Eaton and Kortum (2002), productivities $z(x^a)^{-\theta^a}$ and $z(x^m)^{-\theta^m}$ are assumed to be random variables which have a density function that is exponential with parameters λ_i^a and λ_i^m. $z(x^a)^{-\theta^a}$ and $z(x^m)^{-\theta^m}$ are then amplified by the parameters θ^a and θ^m, which control the variability of x_i^a and x_i^m. The larger the θ^a or θ^m, the more dispersed these productivities are distributed in their respective sectors.

Non-tradeable Sector

The service sector produces a homogenous and non-tradeable good. Its production is given by:

$$y_i^s = (\lambda_i^s)^{-1} s_i^s\,,$$

where s_i^s is the share of labor devoted to producing service, and $(\lambda_i^s)^{-1}$ is country i's productivity in service.

Home Production

In addition to the agricultural production described earlier, workers in the agriculture sector also have access to a "non-market" technology, termed home production. It is assumed that home production produces aggregate agricultural goods only, and the goods it produces are non-tradeable and only for final consumption. Its production is given by:

$$Q_i^{a,h} = A(s_i^{a,h})^{\delta}\,,$$

where $s_i^{a,h}$ is the share of labor engages in home production, and A is the productivity of the home production technology. It is assumed that A is the same across countries, and workers cannot access A unless they work in the agriculture sector.

The addition of home production has two purposes. First, it captures the idea that a significant portion of poor countries' labor in agriculture engages in subsistence farming. These agricultural productions are consumed immediately and not part of the market economy. Second, it enables the model to quantitatively account for cross-country differences in agricultural employment share.[3]

Household Preference

Workers consume three goods: aggregate agricultural good, aggregate manufactured good, and service. The utility function of a worker is:

$$U = \Omega \log(c_a - \bar{a}) + (1 - \Omega) \log(c_m^{\beta} c_s^{1-\beta}) \ .$$

$\bar{a}$ is the term that represents subsistence needs of agricultural goods. Only after each worker consumes $\bar{a}$, she will spend the rest of her income on the three goods. Specifically, she will spend a fixed fraction Ω of her after-subsistence income on agricultural goods (in addition to those for subsistence), a fraction $\beta(1-\Omega)$ on manufactured goods, and a fraction $(1-\beta)(1-\Omega)$ on service goods.

[3]See Section 3.5.4 for a more detailed explanation on the inclusion of home production. It also includes a counterfactual exercise that demonstrates the quantitative effects of home production.

Each worker is endowed with one unit of labor, which she supplies inelastically. Therefore, a worker's budget constraint is her income from working in the tradeable agriculture and manufacturing sectors, as well as the non-tradeable service sector. Subject to her budget, each worker chooses the consumption of agricultural good c_a, manufactured good c_m, and service good c_s to maximize her utility.

3.3.2 International Trade

Only intermediate agricultural goods $q_i^a(x^a)$ and intermediate manufactured goods $q_i^m(x^m)$ are tradeable. Trade costs are assumed to be "iceberg" trade costs, which are the same within sectors, but different across sectors. Respectively, let τ_{ij}^a and τ_{ij}^m be the trade costs on intermediate agricultural goods and intermediate manufactured goods, from country j to country i. It is assumed that $\tau_{ij} > 1$ for $j \neq i$ and $\tau_{ii} = 1$ for all i, as well as that it obeys the triangle inequality: $\tau_{ij} \leq \tau_{ik}\tau_{kj}$ for all i, j, k.

When countries are open to international trade, the producer that delivers the lowest price in country i for $q^a(x^a)$ or $q^m(x^m)$ captures the market for that particular good:

$$\begin{aligned} p_i^a(x^a) &= \min\{p_{ij}^a(x^a) : j = 1, ..., n\}\,, \\ p_i^m(x^m) &= \min\{p_{ij}^m(x^m) : j = 1, ..., n\}\,. \end{aligned}$$

Let w_i^a and w_i^m be the wage rates in agriculture and manufacturing in country

i. Also denote P_i^a and P_i^m as the prices of aggregate agricultural good and aggregate manufactured good in i. Given the constant-return technology of producing intermediate goods $q_j^a(x^a)$ and $q_j^m(x^m)$, it is straightforward to show that

$$\begin{aligned} p_{ij}^a(x^a) &= (x^a)^{\theta^a}(w_j^a)^{\gamma^a}(P_j^a)^{1-\gamma^a}\tau_{ij}^a\,, \\ p_{ij}^m(x^m) &= (x^m)^{\theta^m}(w_j^m)^{\gamma^m}(P_j^m)^{1-\gamma^m}\tau_{ij}^m\,. \end{aligned}$$

By making use of the properties of the extreme value distribution, one can show that the prices of the aggregate agricultural goods and manufactured goods are:

$$P_i^a = \Upsilon\left[\sum_{j=1}^{n}\left[(w_j^a)^{\gamma^a}(P_j^a)^{1-\gamma^a}\tau_{ij}^a\right]^{-1/\theta^a}\lambda_j^a\right]^{-\theta^a}, \tag{3.1}$$

$$P_i^m = \Upsilon\left[\sum_{j=1}^{n}\left[(w_j^m)^{\gamma^m}(P_j^m)^{1-\gamma^m}\tau_{ij}^m\right]^{-1/\theta^m}\lambda_j^m\right]^{-\theta^m}, \tag{3.2}$$

where Υ is a collection of constants.[4] Let D_{ij}^a and D_{ij}^m be country j's share of country i's total spending on agricultural goods and manufactured goods. One can show that:

$$D_{ij}^a = \frac{\left[(w_j^a)^{\gamma^a}(P_j^a)^{1-\gamma^a}\tau_{ij}^a\right]^{-1/\theta^a}\lambda_j^a}{\sum_{k=1}^{n}\left[(w_k^a)^{\gamma^a}(P_k^a)^{1-\gamma^a}\tau_{ik}^a\right]^{-1/\theta^a}\lambda_k^a}\,, \tag{3.3}$$

$$D_{ij}^m = \frac{\left[(w_j^m)^{\gamma^m}(P_j^m)^{1-\gamma^m}\tau_{ij}^m\right]^{-1/\theta^m}\lambda_j^m}{\sum_{k=1}^{n}\left[(w_k^m)^{\gamma^m}(P_k^m)^{1-\gamma^m}\tau_{ik}^m\right]^{-1/\theta^m}\lambda_k^m}\,. \tag{3.4}$$

[4]See Alvarez and Lucas (2007) for a detailed derivation.

3.3.3 Equilibrium

Wage Rates Let w_i^s denote the wage rate in country i's service sector. Let s_i^a and s_i^m denote the shares of a worker's time in the tradeable agriculture and manufacturing sector. Given that $s_i^{a,h}$ denotes the share of a worker's time in home production, the sum of s_i^a and $s_i^{a,h}$ is the share of a worker's time in agriculture.

Labor is assumed to be mobile across sectors. Hence in equilibrium workers must be indifferent between working in each sector. Therefore the manufacturing wage is the same as the service sector wage in equilibrium:

$$w_i^m = w_i^s \,. \tag{3.5}$$

In equilibrium, marginal returns from labor in manufacturing are the same as in agriculture. While the return of one unit of labor in manufacturing is simply w_i^m, the return in agriculture is the sum of returns from working in the tradeable agriculture sector and home production. Equating the marginal returns from these two sectors yields the following equilibrium conditions (see Appendix A for a detailed derivation):

$$w_i^m = w_i^a + (1-\delta)(P_i^a A)^{\frac{1}{1-\delta}}(w_i^a)^{\frac{\delta}{\delta-1}} \,, \tag{3.6}$$

$$s_i^{a,h} = \left(\frac{\delta A P_h^a}{w_i^a}\right)^{\frac{1}{1-\delta}} \,. \tag{3.7}$$

Labor Market Define variable $\bar{a}_i'$ as $\bar{a}_i' = \bar{a} - A(s_i^{a,h})^{\delta}$. $\bar{a}_i'$ is the part of the subsistence of agricultural goods that is not produced by home production.

Define W_i as $W_i = w_i^a s_i^a + w_i^m s_i^m + w_i^s s_i^s - P_i^a \bar{a}_i'$. W_i is a worker's income after subtracting her spending on satisfying subsistence.

In country i, total demand for service is $(1-\Omega)(1-\beta)W_i L_i$. Since labor is the only input used in producing service goods, the equilibrium condition for the service sector is:

$$w_i^s L_i s_i^s = (1-\Omega)(1-\beta)W_i L_i \,. \tag{3.8}$$

For the manufacturing sector, let X_k^m denote country k's total spending on manufactured goods. Country i's manufacturing labor income is equal to labor's share γ^m of country i's manufacturing exports to the world, including home sales:

$$w_i^m L_i s_i^m = \gamma^m \sum_{k=1}^{n} D_{ki}^m X_k^m \,. \tag{3.9}$$

X_k^m has two parts: demand for manufactured goods as intermediate inputs and demand for final consumption:

$$X_k^m = \frac{1-\gamma^m}{\gamma^m} w_k^m L_k s_k^m + (1-\Omega)\beta W_k L_k \,.$$

Therefore from equation (3.9) we have:

$$w_i^m L_i s_i^m = \sum_{k=1}^{n} D_{ki}^m L_k \big[(1-\gamma^m) w_k^m s_k^m + \gamma^m (1-\Omega)\beta W_k\big] \,. \tag{3.10}$$

Similarly, given that a worker's demand for agricultural goods is $P_k^a \bar{a}_i' + \Omega W_k$, for agriculture we have:

$$w_i^a L_i s_i^a = \sum_{k=1}^{n} D_{ki}^a L_k \big[(1-\gamma^a) w_k^a s_k^a + \gamma^a (P_k^a \bar{a}_i' + \Omega W_k)\big] \,. \tag{3.11}$$

Finally, the market clearing condition for the labor market is:

$$s_i^a + s_i^{a,h} + s_i^m + s_i^s = 1\,. \tag{3.12}$$

An equilibrium of the model is characterized by equations (3.5) - (3.8), and (3.10) - (3.12). To solve for an equilibrium of the model is to solve for equilibrium wage rates w_i^a, w_i^m, and w_i^s, as well as equilibrium labor shares $s_i^{a,h}$, s_i^a, s_i^m, and s_i^s.

3.4 Calibration and Parameterization

Calibration of the model includes three parts. First, with the trade costs and the heterogeneity of agricultural productivity estimated in Section 2.4 of Chapter 2, I obtain each country's sectoral "competitiveness" in trade, which is a term that combines a country's production costs and its average efficiency level in the tradeable sector. Second, preference parameters are calibrated to match observed sectoral employment shares. Finally, each country's technology parameters of the tradeable sectors are recovered, and the technology parameter of the non-tradeable sector is calibrated to match each country's real GDP per capita relative to the U.S..

3.4.1 Estimations of Country's "Competitiveness" in Export

A feature of the Eaton-Kortum trade model is that the structural gravity equations that relate bilateral trade flows to sectoral trade costs and the variation of productivity in the tradeable sectors are independent of the consumer's preference and the production structure. Therefore, the underlying structural equations used in estimating sectoral trade costs and the heterogeneity of agricultural productivity in Chapter 2 are the same as those in this essay. Given that the calibration exercise in this essay is based on data from the same group of countries in Chapter 2, in this essay I use the baseline trade costs and the variation of agricultural productivity estimated in Section 2.4.

To estimate trade costs, the following log-linear equation (2.9) is used in Section 2.4:

$$\log\left(\frac{D^a_{ij}}{D^a_{ii}}\right) = S^a_j - S^a_i - \frac{1}{\theta^a}\log\tau^a_{ij}\,.$$

In addition to trade costs, this equation also yields estimates of S^a_j (and similarly S^m_j when (2.9) is applied to manufacturing trade), which represent country j's "competitiveness" in the tradeable sector. They are used to recover country j's technology parameters λ^a_j and λ^m_j in the next section.

3.4.2 Calibration of Preference Parameters

Table 3.1 provides a summary of the calibrated values of remaining parameters.

The parameters γ^a and γ^m are the shares of value added in the production of intermediate agricultural goods and manufactured goods. As GTAP provides data on payments to labor, land, and capital, I use the sum of these payments to subtract from gross production for each country. The values of γ^a and γ^m are the average shares for the sample countries.

I use 2.0 for η as it is the value commonly used in the literature. It has no quantitative importance on the results of this essay.[5]

Home production technology has two parameters: δ and A. By the very nature of home production, there are very limited empirical data that can help pin down the values of these two parameters. δ is the return on labor in home production and directly controls how quickly home production decreases as labor input increases. As home production in the model can be thought as a way for agricultural workers to produce own consumption, it corresponds to the "traditional technology" in Gollin et al (2007). In their study, Gollin et al use 0.7 for labor share, which they bare on historical data on agricultural production. As for A, it is calibrated using data on the share of food consumption that is

[5]Chaney (2008) provides an explanation as to why this is true.

produced at home in Brazil.[6] Using data from the Living Standards Measurement Study Survey by the World Bank, Deaton and Zaidi (2002) report that the share of food consumption produced by home production was 0.26 in 1997 in Brazil.

With estimates obtained in Section 3.4.1, I calculate the prices of aggregate goods in the tradeable sectors:

$$\hat{P_i^a} = \Upsilon\Big[\sum_{j=1}^{n} e^{\hat{S_j^a}} \hat{\tau_{ij}^a}^{\frac{-1}{\hat{\theta^a}}}\Big]^{-\hat{\theta^a}},$$
$$\hat{P_i^m} = \Upsilon\Big[\sum_{j=1}^{n} e^{\hat{S_j^m}} \hat{\tau_{ij}^m}^{\frac{-1}{\hat{\theta^m}}}\Big]^{-\hat{\theta^m}}.$$

With $\hat{P_i^a}$, $\hat{P_i^m}$, D_{ij}^a, and D_{ij}^m and given values of Ω, $\bar{a}$, β, and A, one can solve for equilibrium wage rates and labor shares in the model. To calibrate Ω, $\bar{a}$, β, and A, I target four moments in the data: the average agricultural employment shares of the five countries with the smallest agricultural employment shares, the average agricultural employment shares of the five countries with the largest agricultural employment shares, the average ratio of manufacturing employment shares to service employment shares, and home production's share of food consumption in Brazil.

Ω governs the spending on agricultural goods after satisfying subsistence. Its value is sensitive to the small agricultural employment shares observed in

[6]The Living Standards Measurement Study Survey has home production data from only two countries: Brazil and Vietnam. The Brazilian data are the only one that can be accessed by the public.

rich countries, since in these countries only a small part of agricultural production is used in satisfying subsistence. On the other hand, the value of $\bar{a}$ is sensitive to the large agricultural employment shares observed in poor countries, since in these countries agricultural employment is mainly used in producing agricultural goods for subsistence. The value of β determines the relative shares of after-subsistence spending on manufactured goods and service goods, which in turn determines the relative employment shares of these two sectors. Finally, given home production's share of food consumption in Brazil, the value of A can be pinned down by (3.7).

The last step is to recover technology parameters λ_i^a, λ_i^m, and λ_i^s. Given S_i^a, S_i^m, P_i^a, and P_i^m, I back out λ_i^a, λ_i^m from equation (2.10). To calibrate λ_i^s, I solve for the price of the service good P_i^s by matching it to each country's real GDP per capita relative to the U.S.. λ_i^s is then recovered from $\lambda_i^s = w_i^s / P_i^s$.[7] Values of the technology parameters can be found in Table 3.2.

3.4.3 Sectoral Comparative Advantage in Trade

λ_i^a and λ_i^m recovered in the last section represent the average efficiency levels of each country's tradeable sectors. They also provide a measure of each country's sectoral comparative advantage in trade.[8]

[7] The procedure of calibrating technology of service is similar to that in Duarte and Restuccia (2010).

[8] Note that here comparative advantage in trade is defined by the ratio of λ_i^a to λ_i^m, which makes it a measure of technology differences. In contrast, Tombe (2011) defines comparative advantage in trade as differences not only in technology but also in wages rates. In Tombe (2011) poor countries' comparative advantage in trade is in agriculture, which appears to be

In the standard Eaton-Kortum model where only one tradeable sector exists, all trade occurs within that one sector. The extent of trade is governed by two factors: trade costs and the variation of individual productivity in the tradeable sector. In addition to *intra-sectoral* trade, the model in this essay also allows for trade between the tradeable agriculture and manufacturing sectors. This *inter-sectoral* comparative advantage is governed by the ratio of a country's average productivity of its two tradeable sectors: $\frac{(\lambda^a)^{\theta^a}}{(\lambda^m)^{\theta^m}}$. Figure 3.3 shows that this ratio is generally higher in rich countries than in poor countries, which suggests that poor countries' comparative advantage in trade is in manufacturing.

3.5 Counterfactual Exercises: The Food Problem and Gains from Trade

To investigate the potential gains from trade, the calibrated model is used to evaluate the effects of lowering trade costs. In the first set of counterfactuals, trade costs are set to zero, first on both tradeable goods then on each of them individually. I find that potential gains of frictionless trade are substantial and much larger for poor countries with high baseline agricultural employment share. The second set of counterfactuals includes two exercises: (i)

the opposite of this essay's finding. However, it is mainly driven by poor countries' much lower agricultural wages. If measured by technology only, in Tombe (2011) poor countries' comparative advantage in trade is in manufacturing, which is consistent with this essay's finding.

setting trade costs to infinity (autarky); (ii) lowering trade costs incrementally. I find that reductions on real income are small in autarky. Moreover, gains from trade are non-linear, and larger gains occur in the last reductions of trade costs. Moving from 20% of the baseline trade costs to 0% delivers more than 50% of the total gains from trade. Finally, to assess the quantitative implications of subsistence and home production, I perform two counterfactuals where these two features are dropped from the benchmark model. I find that a model without subsistence and home production underestimates gains from trade for poor countries by as much as 50%.

Countries are divided into four reporting groups according to the size of their baseline agricultural employment shares.[9] Table 3.3 provides summary statistics for the four groups. Notice that group 1 is the only group that has substantial agricultural employment shares, which suggests the existence of the food problem. The other three groups have modest to minimal agricultural employment, which suggests the absence of the food problem. This difference proves to be crucial for the results of the counterfactuals.

3.5.1 Complete Frictionless Trade with Subsistence

How large are gains from trade if all trade costs are eliminated? The answer to this question gives a measure of all potential gains from trade available for

[9] An alternative is to divide countries according to real income per capita. The results of the counterfactuals will be very similar as real income per capita has strong negative correlation with agricultural employment shares. Sorting according to agricultural employment helps sharpen the results and highlight the key mechanisms of the model.

the sample countries. More importantly, it illustrates the key mechanisms as to how these gains are realized.

Eliminating all trade costs results in substantial increases in both trade volume and trade intensity (total trade volume/gross production). For the world economy, trade intensity of agricultural goods increases from 0.034 to 1.80, while trade intensity of manufactured goods increases from 0.17 to 1.88.

These increases in trade leads to substantial increases in real GDP per capita, ranging from 34% (Japan) to 667% (Uganda).[10] Countries with high baseline agricultural employment shares - poor countries - gain much more than those with low agricultural employment shares - rich countries.[11] As Figure 3.4 shows, countries in the bottom quartile enjoy the largest average increase in real GDP per capita (over 330%) and countries in the top quartile have the smallest increase (about 70%). Moreover, cross-country differences, as measured by the variance of log of real GDP per capita, decrease from 0.93 in baseline to 0.53 in frictionless trade - a 43% reduction.

It is worth emphasizing the magnitude of the increase in GDP. For countries in group 1, which in the past 10 years on average had been growing at the rate of 2.5% per year, the increase in real GDP is equivalent to 49 years of continuous growth. For countries in group 4, which on average had been growing at

[10]Changes in real GDP are calculated using the chain-weighted method. Cross-country income differences are calculated using the Geary-Khamis method employed by the Penn World Table.

[11]The correlation between agricultural employment shares and increases in real GDP per capita is 0.9, while the correlation between country's real GDP per capita relative to U.S. and increases in real GDP per capita is -0.65.

the rate of 2.1% per year, it is equivalent to 27 years of continuous growth. Relative to the existing literature, gains from trade in this essay are also large. For example, in Eaton-Kortum (2002) welfare gains from frictionless trade range from 16% (U.S.) to 24% (Greece). As a study in the literature that finds large potential gains from trade, in Waugh (2009) cross-country income differences decrease by 42% (from 1.3 to 0.76) after trade costs are eliminated.

The key to understanding the large differences in gains from trade across countries is the differences in the reallocation of labor triggered by lower trade costs. Moving from the baseline to frictionless trade, *all* countries experience substantial labor reallocation *within* their tradeable sectors due to foreign competition. This is because lower trade costs inevitably results in some tradeable goods that were initially produced domestically being displaced by foreign competition. The labor that were previously used to produce these goods are reallocated to more productive firms. As documented in Table 3.4, this reallocation can be very extensive and results in substantial increase in sectoral labor productivity. In the baseline, each country on average produces more than 95% of the agricultural goods and about 81% of the manufactured goods domestically. With zero trade costs, each country specializes in producing a small set of tradeable goods and becomes the only producer of those goods in the world. As a result, for the world economy output per worker in agriculture increases more than 800%, while output per worker in manufacturing increases by about 250%.

What drives the much larger gains from trade for countries in the bottom quartile is the *cross-sector* reallocation of labor. As Figure 3.5 shows, countries in the bottom quartile experience significant reallocation of labor from agriculture to manufacturing and service, while cross-sector labor movements are modest to minimal for the other three quartiles. This is due to two factors. First, because of the low income elasticity of agricultural goods, the substantial increase in agricultural labor productivity is accompanied by a modest increase in the demand for these goods. For the world economy, output per worker increases by 872% while total demand for agricultural goods only increases by about 47%. As a result, large amounts of surplus labor appear in agriculture, and the majority of them reside in poor countries.

Second, given that poor countries' comparative advantage in trade is generally in producing manufactured goods, countries in group 1 and group 2 reallocate labor from agriculture to manufacturing after trade costs are set to zero. As Figure 3.6 shows, from being marginal net importers in baseline, countries in group 1 and 2 have become significant net importers of agricultural goods in frictionless trade. This enables poor countries to focus their labor on producing manufactured and service goods. Compared to the production of agricultural goods, this results in higher output per worker and, as a result, leads to increases in poor countries' income levels.

To summarize, lowering trade costs helps poor countries overcome the food problem by both increasing labor productivity in agriculture and allowing poor countries to import agricultural goods. As these countries no longer need to devote large fractions of their labor in agriculture to satisfy subsistence needs, they enjoy substantial increases in real income by reallocating their agricultural labor to the more productive non-agriculture sector.

3.5.2 Frictionless Trade in Manufacturing and Agriculture

To further decompose the sources of gains from trade, I consider two counterfactuals where trade costs on agricultural goods and manufactured goods are eliminated individually.

As Figure 3.4 shows, except for countries in group 1, gains from eliminating trade costs on manufactured goods represent more than 80% of the entire gains from trade. For group 3 and 4, free trade in manufactured goods delivers more than 95% of the total gains. This is not the case for countries in group 1. While both deliver substantial gains from trade, free trade in agriculture delivers slightly more gains than free trade in manufacturing. In fact, for the five countries with the highest agricultural employment shares in baseline, gains from free agricultural trade are about 50% higher than gains from free manufacturing trade.

An examination of Figure 3.4 and Figure 3.5 also reveals the limitation of allowing free trade in only one sector for countries in group 1. As Figure 3.6 indicates, in both counterfactuals, countries in group 1 become modest net importers of agricultural goods and experience reductions in their agricultural employment shares. However, this labor reallocation is inhibited by the high trade costs that remain in the other tradeable sector. In free manufacturing trade, countries in group 1 benefit because their comparative advantage lies in producing manufactured goods. We therefore observe an increase in manufacturing employment and reduction in agricultural employment. However, to maintain subsistence, these countries need to import agricultural goods, which carry very high trade costs. Hence the reduction in agricultural employment in these countries fall well short of that in complete frictionless trade.

On the other hand, when trade costs on agricultural goods are eliminated but those on manufactured goods remain, the reallocation from agriculture to other sectors is inhibited by the fact that high trade costs on manufactured goods prevent these countries from exporting manufactured goods to pay for their agricultural imports. This is the reason that the reallocation of labor in agriculture is mainly to service, not to manufacturing.

Another important observation is that, unlike the other three groups, for countries in group 1 the gains from eliminating trade costs on both sectors are substantially (about 50%) larger than the sum of the gains delivered by eliminating trade costs on each sector independently. This shows that, while for rich and middle income countries free manufacturing trade is the main generator for gains, the full potential gains from trade for poor countries are realized by eliminating trade costs on *both* agricultural and manufactured goods.

3.5.3 The Non-Linearity of Gains from Trade

This section includes two counterfactual exercises. First, trade costs on tradeable goods are set to infinity. The estimated gains (or rather loss) from trade by moving to autarky is an indication of how much gains have been realized due to the current levels of trade. Second, to examine the non-linearity of the potential gains from trade, trade costs are reduced incrementally, from 100% to 0% of their baseline value.

From Baseline to Autarky

How far is the world from autarky? I answer this question by setting trade costs on each of the tradeable goods to infinity ($\tau_{ij}^a = \tau_{ij}^m = +\infty$) and examine the change of real GDP per capita.

As Figure 3.7 shows, the impact of moving to autarky is relatively small for all four groups. The largest average *decrease* is less than 4% (group 2) across four groups. Compared to the estimated potential gains from frictionless agricultural trade and frictionless manufacturing trade, the small decreases in real GDP per capita in autarky is an indication of how punitive the existing trade costs are. Countries are not much worse off if trade does not occur at all.

Gains from Trade with Incremental Reductions on Trade Costs

In this counterfactual I study how potential gains from trade vary at different levels of trade costs. Three cases are considered: lowering trade costs on agricultural goods only, lowering trade costs on manufactured goods only, and lowering both trade costs simultaneously with the same percentage reduction.

As Figure 3.8 shows, gains from trade are concentrated in the last reductions of trade costs. For all four groups, reducing trade costs by the first 50% delivers less than 20% of the total potential gains from trade. For rich countries with low agricultural employment shares (group 3 and 4), the gains from lowering trade costs on manufactured goods are almost identical to the total gains from trade in each percentage reduction.

An important observation from Figure 3.8 is that, for countries in the bottom quartile (group 1), agricultural trade consistently delivers higher gains than manufacturing trade for the same percentage reduction on trade costs. Moreover, although the larger gains are concentrated in the last reductions of trade costs, for poor countries (group 1) significant gains from trade are obtainable with plausible reductions on agricultural trade costs. For instance, a 20% reduction on agricultural trade costs, which still makes them about 60% higher than the existing manufacturing trade costs, delivers about 10% increase in real GDP per capita for countries in group 1, while the same percentage reduction on manufacturing trade costs delivers less than 2% increase.[12] When agricultural trade costs are lowered to equal to the level of baseline manufacturing trade costs (about 45% reduction), the average increase in real GDP per capita for group 1 is approximately 22%. This is equivalent to more than 8 years of continuous growth for countries in the bottom quartile.

One might wonder whether the previously mentioned reductions on agricultural trade costs are plausible. As Appendix B shows, these reductions are possible if countries can reduce their policy barriers (both tariffs and nontariffs barriers) and transport costs on agricultural goods so that they are more similar to those on manufactured goods. For example, at least 9.8% and as much as 25.4% of the existing agricultural trade costs can be eliminated by setting trade policies and transport costs on agricultural goods to those on manufactured goods.[13] Doing so can also remove at least 19.6% and up to 47.2% of the differences between the estimated trade costs on the two tradeable goods.

In additional to reducing trade policies and transport costs on agricultural goods to those on manufactured goods, there are also substantial scopes for

[12]This is also true when the *magnitudes* of the reduction are the same. A 20% reduction on agricultural trade costs is roughly equal to a 45% reduction on manufacturing trade costs. This magnitude of reduction on manufacturing trade costs leads to about 6% increase in real GDP per capita.

[13]Note that policy barriers and transport costs are two components of the estimated trade costs in this essay. The broadly defined trade costs in this essay also include many other costs associated with getting a good from a country to the final user in another country, such as language costs, currency costs, and legal costs. See Appendix B for a more in-depth discussion.

poor countries to reduce agricultural trade costs by improving their transportation infrastructure. As Adamopoulos (2011) reports, there exist large cross-country differences in transportation infrastructure, with the poorest 5% countries in the world having only about 1/32 of the infrastructure stocks of the richest 5% countries'. As a result, transport costs in the 5% poorest countries are about 2.4 times larger than those in the richest 5% countries. While it is probably unreasonable to expect them to completely catch up with rich countries in the short-run, poor countries, according to Appendix B, will be able to reduce their agricultural trade costs by about 9.6% to 25% by reducing the gap between their transport costs to those of the rich countries' by half.

The above discussion suggests that reducing poor countries' agricultural trade costs by 20% is possible given the current technology. Moreover, if poor countries can reduce their policy barriers on agricultural goods and improve their transportation infrastructure, it may be possible to reduce the estimated agricultural trade costs to the levels of the baseline manufacturing trade costs.

3.5.4 Effects of Subsistence and Home Production

Two of the key features of my model are the minimum consumption and home production of agricultural goods. In this section, I examine their quantitative roles on assessing gains from trade.

Complete Frictionless Trade without Subsistence and Home Production

To isolate the quantitative importance of the food problem, I study a variant of the model where subsistence and home production are dropped. In this framework, each country's tradeable sector employs the same fraction of labor, and there is no difference between the demand for agricultural goods and the demand for manufactured goods. Furthermore, all reallocation of labor occurs only within the tradeable sector. This model corresponds to the framework in Alvarez and Lucas (2007) and Waugh (2009).

Without subsistence, the utility function becomes:

$$U = c_a^{\beta} c_m^{\beta} c_s^{1-2\beta}\,.$$

In essence, I eliminate the subsistence part in the demand for agricultural goods and make the demand for agricultural goods same as the demand for manufactured goods. In this framework, there is no food problem. I also omit the home production technology and set β to 0.125.[14] Each country's tradeable sector consists of two parts: agriculture and manufacturing. Together these two sectors employ 25% of workers. As Figure 3.9 shows, in the benchmark economy, there exist very little differences in sectoral composition across countries.[15]

[14]The value 0.125 is chosen to ensure that the tradeable sector employs 25% of the total number of workers, which is the size of the tradeable sector in Alvarez and Lucas (2007) and Waugh (2009).

[15]The model is not re-calibrated. Except for the parameters of the utility function and that

As Figure 3.10 shows, while gains from trade do not differ significantly for countries in group 2 to 4, for poor countries with high baseline agricultural employment shares (group 1) gains from trade are about 50% higher in a model with subsistence needs and home production.

The significant difference between the two sets of results in Figure 3.10 highlights the importance of the food problem for assessing gains from trade. There are two reasons why gains from trade are substantially smaller for poor countries in the framework without subsistence and home production. First, by underestimating poor countries' agricultural employment shares, the model undervalues the amount of labor in poor countries' tradeable sectors. After trade costs are eliminated, less labor reallocation occurs, which results in less efficiency gains. Second, this model shuts down the channel of cross-sector labor reallocation, which is the main driver of poor countries' much larger gains from trade in my model with subsistence and home production.

Gains from Trade without Home Production

Without home production, the model consistently underestimates agricultural employment shares for most sample countries. This is because in the model spending on agricultural goods cannot exceed total income. This sets an upper bound for the calibrated value of the subsistence term $\bar{a}$. Among the 46 sample

home production is dropped, the same values are used for the remaining parameters in the model. This is to ensure that the differences in gains from trade depicted in Figure 3.10 are not due to differences in parameter values.

countries in this paper, three (Malawi, Uganda, Vietnam) have per capita income of equal or less than one U.S. dollar a day. As subsistence $\bar{a}$ is calibrated to match these countries' extremely low levels of income, it proves to be too low to quantitatively account for the agricultural employment shares of most sample countries (see Figure 3.11).

One possible explanation is that per capita income of one U.S. dollar a day is *not* enough for subsistence.[16] The reason workers in least-developed countries survive with equal or lower than one U.S. dollar a day is that part of their agricultural production and consumption is not accounted for in the official statistics of output. As wage rates are very low in these poor countries, workers might be better off by devoting a fraction of their time at home to produce part of their agricultural consumption. These agricultural productions do not enter the market economy. As a result, they are not counted as part of workers' income.

Figure 3.11 shows that a model that accounts for the possibility of home production does a better job at matching the agricultural employment shares observed in the data.[17] More importantly, as Section 3.5.1 shows that the gains from trade are highly correlated with a country's baseline agricultural employment shares, a model without home production could significantly underestimates potential gains from trade for poor countries.

[16]For studies that emphasize the role of home production in poor countries, see Locay (1990), Parente et al (2000), and Gollin et al (2004).

[17]Without home production, the correlation of agricultural employment in baseline and agricultural employment in the data is 0.72, while it is 0.88 with home production.

To see the quantitative implications of home production on gains from trade, I recalibrate the model without home production and perform the counterfactual exercise of eliminating all trade costs. Figure 3.12 shows that, for poor countries with the food problem (countries in group 1), potential gains from complete frictionless trade are noticeably smaller in the model without home production.

3.6 Conclusion

In a quantitative general equilibrium trade model, I show that potential gains from trade are substantial and much larger for poor countries when the food problem is present. Lowering trade costs leads to poor countries' large gains in two ways. First, reducing agricultural trade costs leads to substantial increase in labor productivity in agriculture for the world economy. Combined with the low income elasticity of agricultural goods, this creates large amount of surplus labor in agriculture, the majority of which reside in poor countries. Second, poor countries no longer need to devote as much labor in agriculture because the lower trade costs on both tradeable goods enable them to become large net importers of agricultural goods and net exporters of manufactured goods.

While being agnostic about the causes of the estimated trade costs, this essay finds that significant gains from trade for poor countries are present with plausible reductions on agricultural trade costs. Specifically, a 20% reduction on agricultural trade costs delivers about 10% increase in real GDP per capita for countries in the quartile with the highest agricultural employment shares. When agricultural trade costs are set to equal to manufacturing trade costs, the average increase in real GDP per capita is about 22%. Considering that in the past ten years the average annual growth rate in real income per capita was 2.5% for these countries, the increases in real income are substantial.

When gains from trade are evaluated in a model without subsistence and home production, I find that potential gains from trade for poor countries can be underestimated by as much as 50% relative to this essay's benchmark model. This finding highlights the importance of including key insights of the food problem on assessing gains from trade for poor countries.

In summary, the analysis of this essay shows that there exist large unrealized gains from trade for poor countries with the food problem. Moreover, lowering trade costs on agricultural goods is the key to realizing these gains. Finally, when assessing gains from trade for poor countries, it is important to consider the quantitative effects of subsistence needs and home production of agricultural goods.

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Table 3.1: Values of parameters

Parameter	Description	Value
θ^m	variation of technology in manufacturing	0.18
γ^a	share of value added in agriculture	0.41
γ^m	share of value added in manufacturing	0.33
δ	share of labor in home production	0.70
η	elasticity of substitution in aggregating intermediate agricultural goods and manufactured goods	2.0
Ω	share of income spent on agricultural goods after subsistence	0.0057
β	share of income spent on manufactured goods after consuming agricultural goods	0.27
$\bar{a}$	subsistence needs of agricultural goods	1131
A	labor productivity of home production	963

Table 3.2: Estimated parameters of technology

Country	$\left(\frac{\lambda_i^a}{\lambda_{u.s.}^a}\right)^{\theta^a}$	$\left(\frac{\lambda_i^m}{\lambda_{u.s.}^m}\right)^{\theta^m}$	$\frac{\lambda_i^s}{\lambda_{u.s.}^s}$
Australia	0.82	0.84	0.83
New Zealand	0.97	0.93	0.66
China	0.44	0.51	0.20
Japan	1.35	1.36	0.70
Korea	1.07	1.08	0.58
Indonesia	0.36	0.42	0.58
Malaysia	0.85	0.86	0.28
Philippines	0.35	0.41	0.53
Thailand	0.50	0.58	0.24
Vietnam	0.22	0.33	0.35
Bangladesh	0.27	0.36	0.20
India	0.34	0.39	0.23
Sri Lanka	0.26	0.35	0.17
Canada	0.97	0.97	0.74
United States	1.00	1.00	1.00
Mexico	0.66	0.68	0.39
Columbia	0.33	0.40	0.39
Peru	0.45	0.53	0.20
Venezuela	0.46	0.53	0.45
Argentina	0.86	0.81	0.43
Brazil	0.68	0.70	0.31
Chile	0.60	0.59	0.47
Uruguay	0.47	0.49	0.48
Austria	1.08	1.00	0.69
Belgium-Luxembourg	1.13	0.99	0.82
Denmark	1.05	1.02	0.66
Finland	1.25	1.18	0.45
France	1.13	1.07	0.63
Germany	1.16	1.13	0.54
United Kingdom	0.94	0.92	0.67
Greece	0.53	0.57	0.69
Ireland	1.36	1.15	0.64
Italy	1.17	1.14	0.72
Netherlands	1.03	0.98	0.73
Portugal	0.74	0.78	0.52
Spain	0.81	0.84	0.70
Sweden	1.18	1.14	0.47
Switzerland	1.33	1.21	0.43
Hungary	0.63	0.64	0.39
Poland	0.46	0.53	0.38
Turkey	0.41	0.47	0.37

Table 3.2: Estimated parameters of technology (continued)

Country	$\left(\frac{\lambda_i^a}{\lambda_{u.s.}^a}\right)^{\theta^a}$	$\left(\frac{\lambda_i^m}{\lambda_{u.s.}^m}\right)^{\theta^m}$	$\frac{\lambda_i^s}{\lambda_{u.s.}^s}$
Morocco	0.40	0.49	0.25
Malawi	0.25	0.35	0.14
Zambia	0.39	0.44	0.13
Zimbabwe	0.34	0.41	0.21
Uganda	0.23	0.30	0.09

Table 3.3: Summary statistics of four reporting groups

	Num. of Countries	Ave. Ag. Employment	Rela. Real GDP per capita	Ave. Annual Growth in Past 10 Years
Group 1	11	0.58	0.16	2.5%
Group 2	12	0.19	0.41	3.0%
Group 3	12	0.06	0.87	2.5%
Group 4	11	0.03	1.00	2.1%

Table 3.4: Domestic shares of tradeable goods and their impacts on labor productivity

	Share of Goods Produced Domestically				Increases in Sectoral Labor Productivity	
	Baseline		Frictionless Trade			
	Ag	Mnfcs	Ag	Mnfcs	Ag	Mnfcs
Group 1	0.97	0.81	0.01	0.008	477%	734%
Group 2	0.94	0.79	0.02	0.02	361%	396%
Group 3	0.96	0.83	0.02	0.02	645%	657%
Group 4	0.94	0.83	0.04	0.05	421%	287%
World	0.95	0.81	0.02	0.02	872%	253%

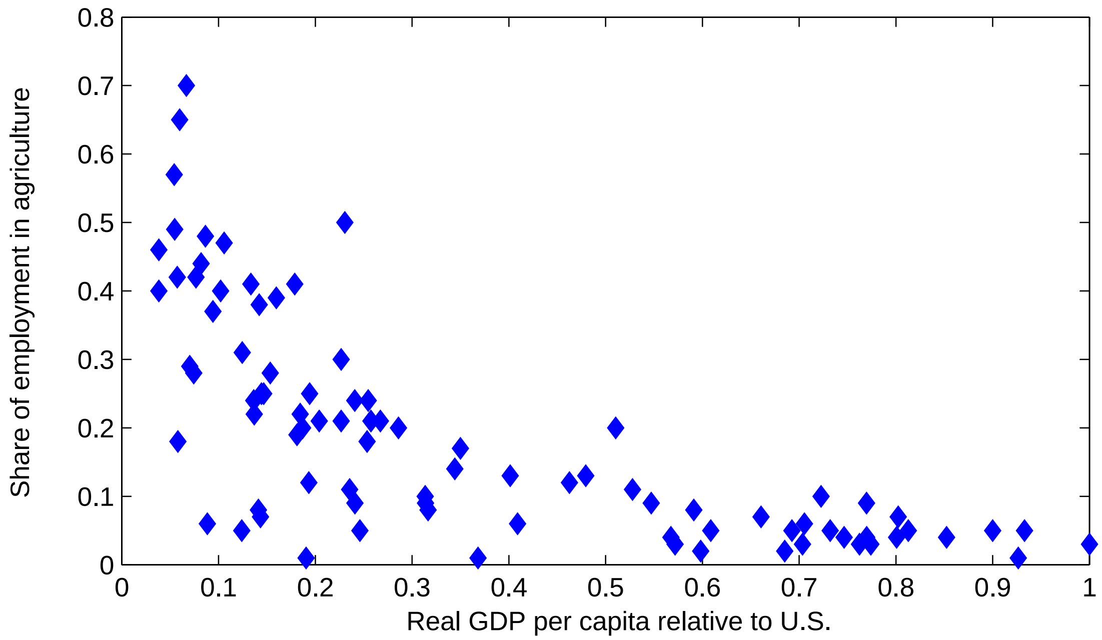

Figure 3.1: Shares of employment in agriculture in 1997

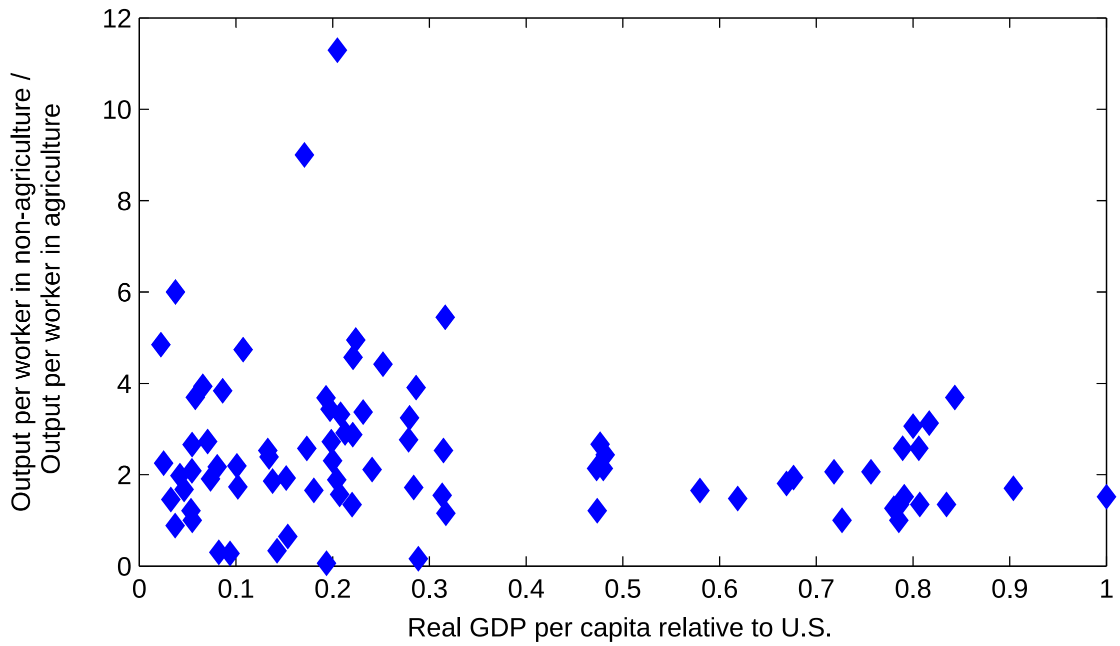

Figure 3.2: Relative productivity of non-agriculture to agriculture in 1997

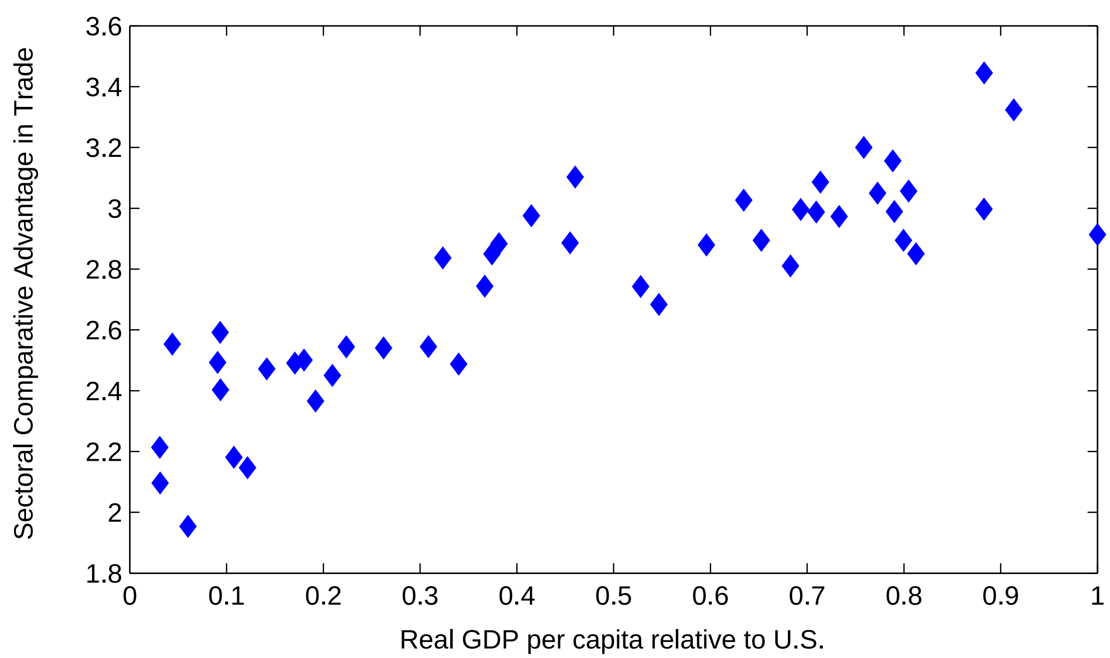

Figure 3.3: Sectoral comparative advantage in trade: $\frac{(\lambda^a)^{\theta^a}}{(\lambda^m)^{\theta^m}}$

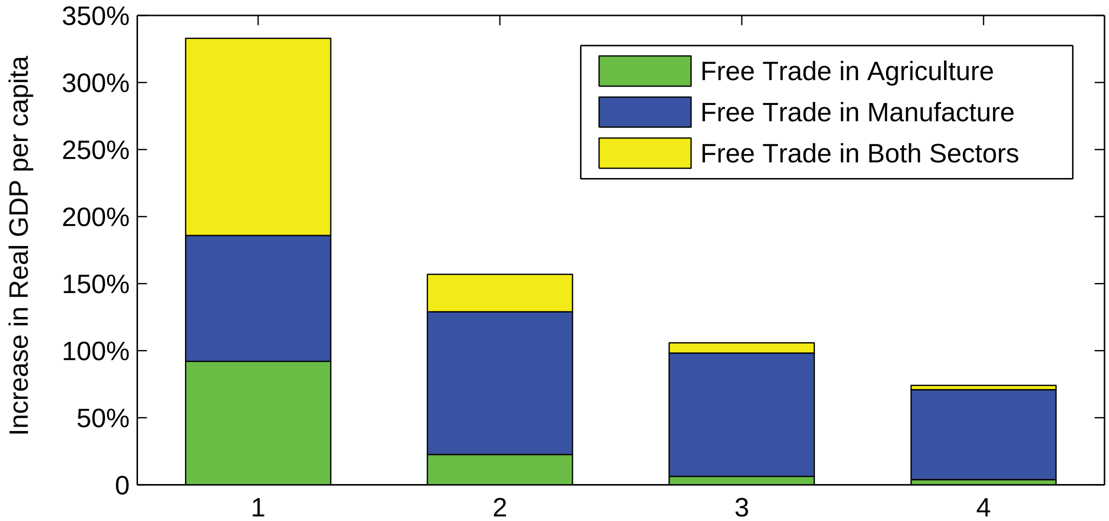

Figure 3.4: Gains from trade: increase in real GDP per capita

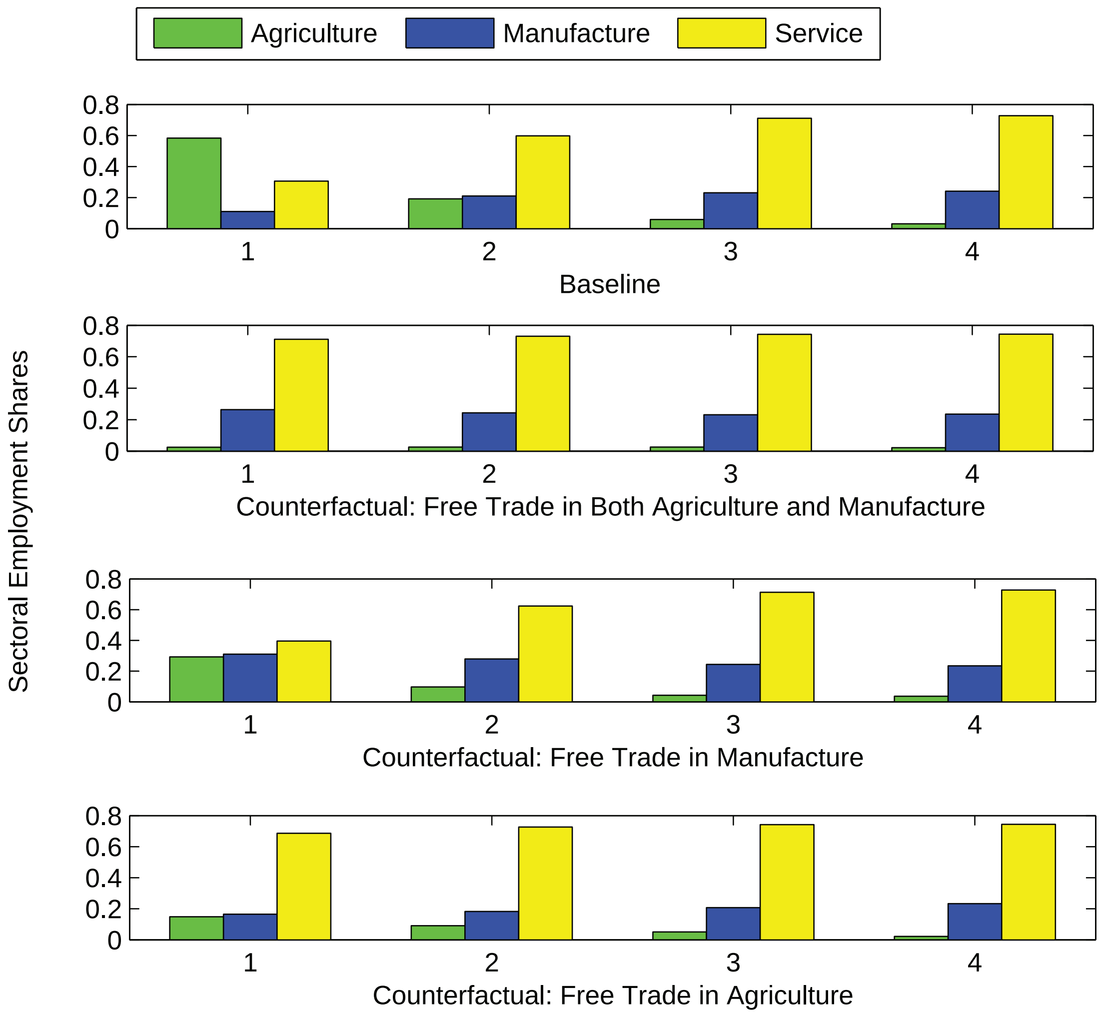

Figure 3.5: Employment shares in baseline and counterfactuals

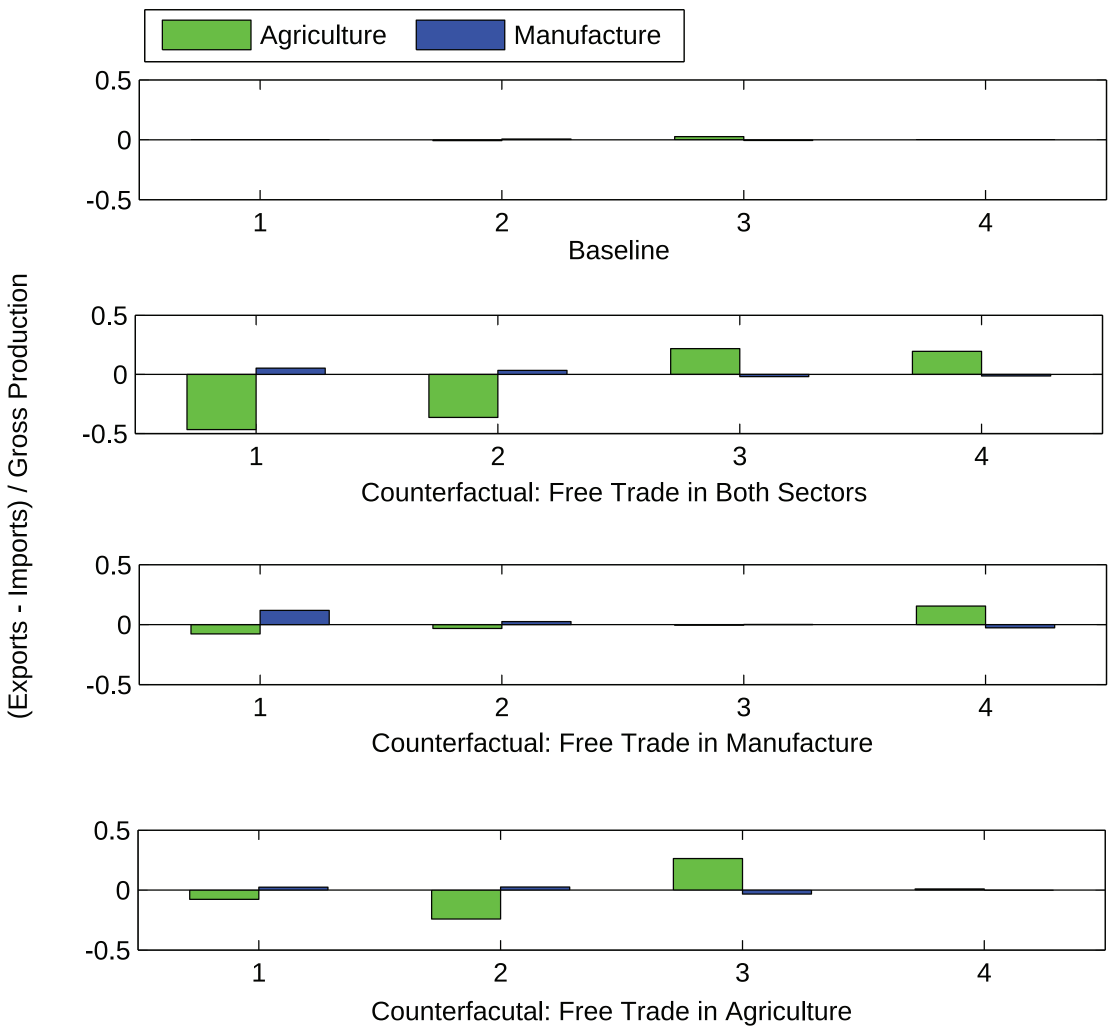

Figure 3.6: Net trade between agriculture and manufacture

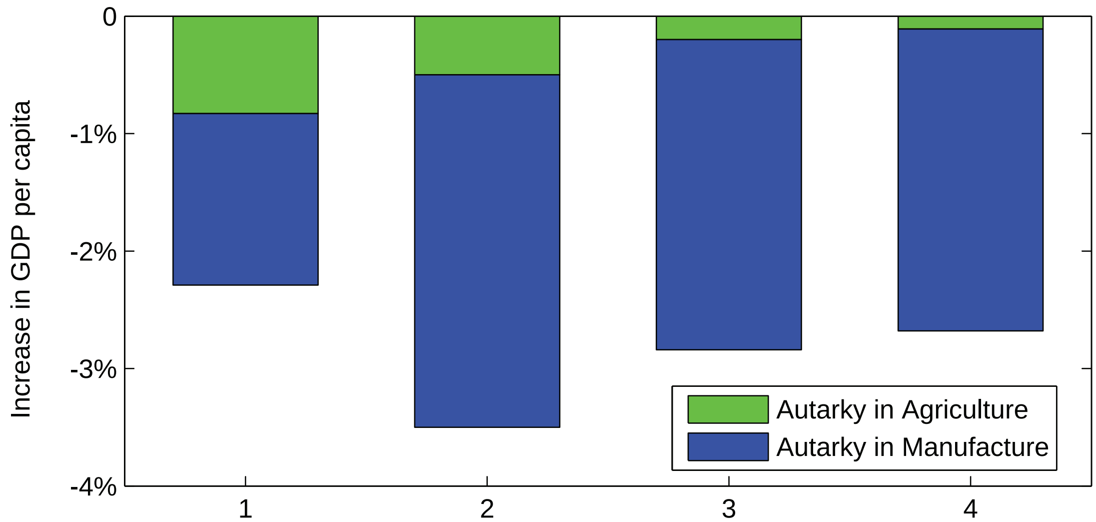

Figure 3.7: Gains from trade: increase in real GDP per capita

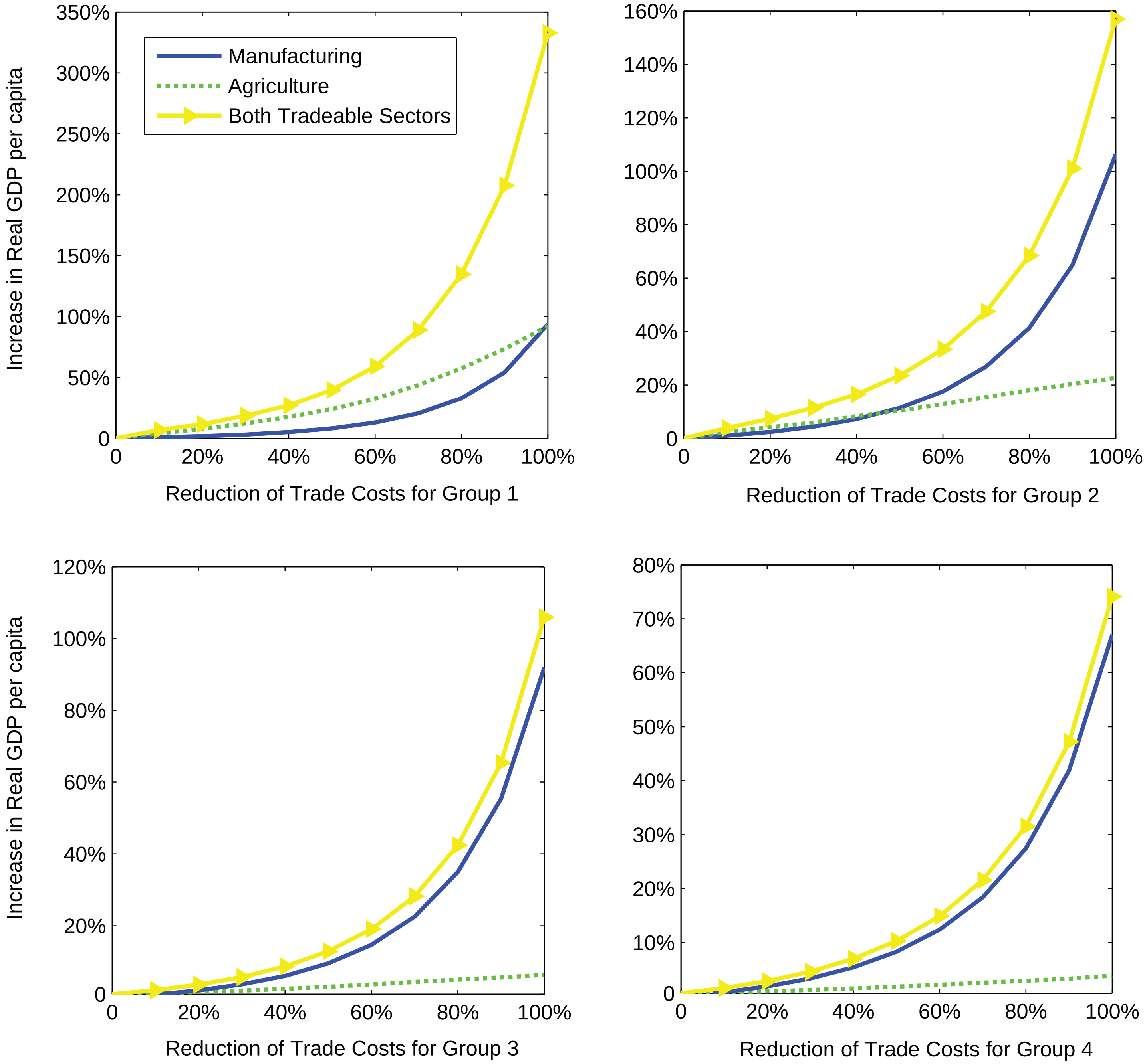

Figure 3.8: Gains from trade from reductions of trade costs.

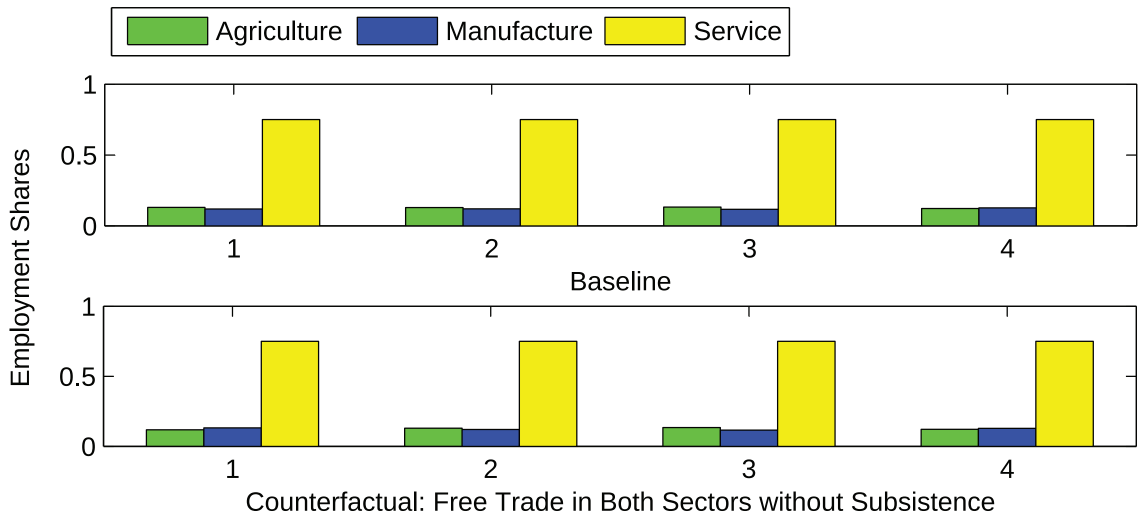

Figure 3.9: Employment shares in baseline and counterfactuals

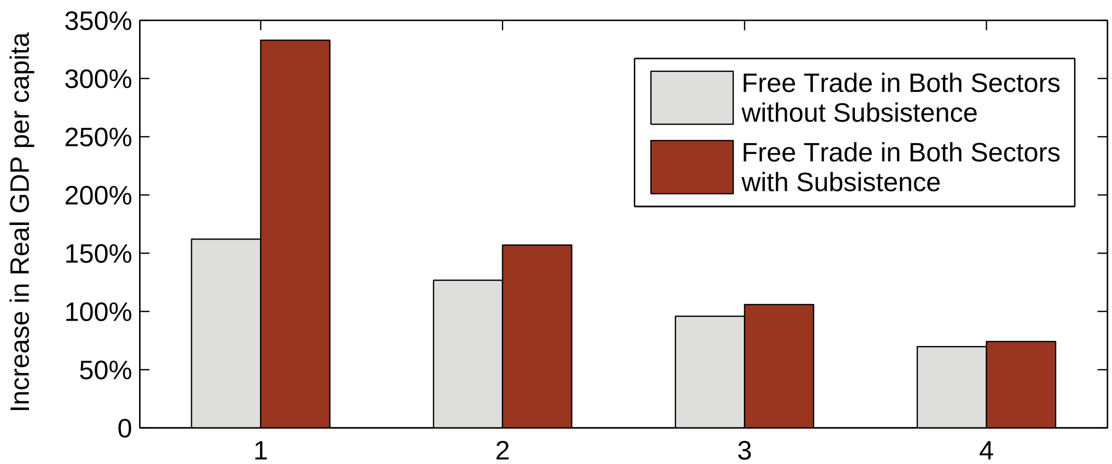

Figure 3.10: Gains from trade: increase in real GDP per capita

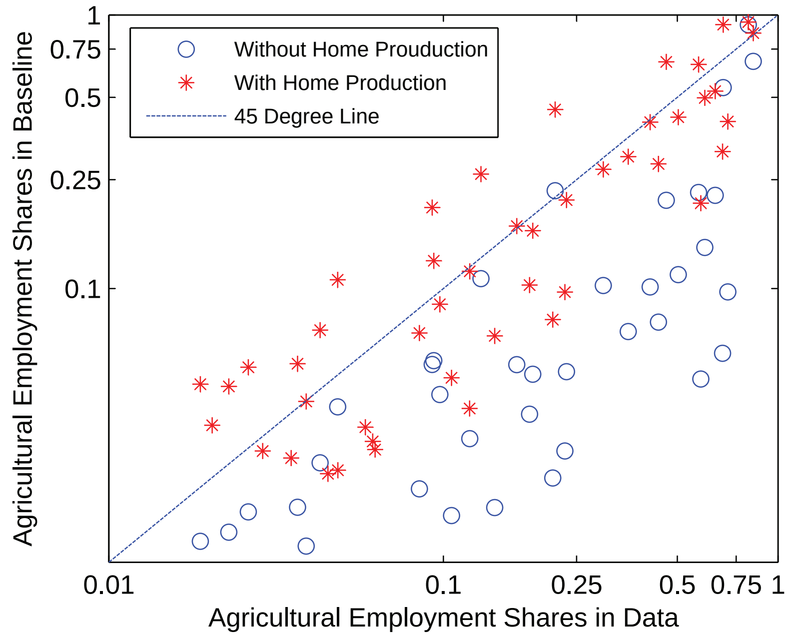

Figure 3.11: Agricultural employment shares: with and without home production

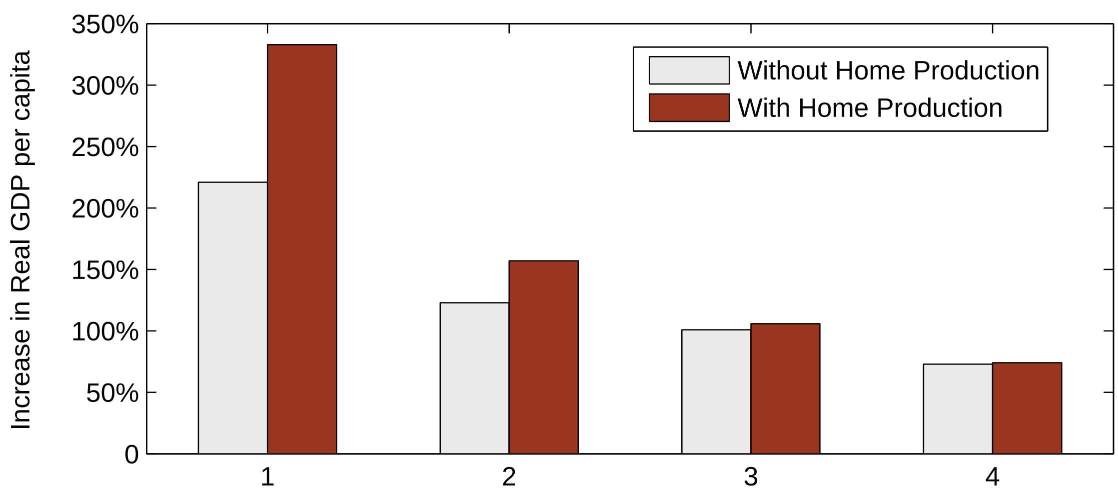

Figure 3.12: Gains from trade: with and without home production

Chapter 4

Barriers to Labor Mobility and International Trade: The Case of China

4.1 Introduction

The Household Registration System, commonly referred to as the Hukou system, is an important institution in China and has attracted much attention from the research community. By denying migrant workers access to some basic publicly provided goods such as health care, housing, and education, the Hukou system in effect discourages the reallocation of labor from agriculture to non-agriculture in China. A number of studies argue that Hukou represents an important labor market distortion and has been a major contributing factor to a wide range of issues in China, such as its growing income inequality.[1]

While reforming Hukou will most certainly impact China's economy, there

[1] Examples include Cai et al (2002), Zhu (2002), Fleisher and Yang (2003), Liu (2005), and Whalley and Zhang (2007).

are reasons to believe that the rest of world may also be affected. This is especially true when one considers the size of China's economy and its population, as well as China's share in world trade. For example, in 2009, China's GDP was 8.6% of the world GDP, and its labor made up 24.7% of the world labor force (World Development Indicator 2009). In the same year, 9.7% and 13.1% of world's merchandize and manufacturing exports were from China.

Motivated by the importance of Hukou to China's economy and China to the world economy, this essay examines the impact of reforming the Hukou system on both China and the rest of the world. Specifically, this essay asks: What are the possible impacts of eliminating the Hukou system on the income level and the sectoral composition of China as well as those of other individual economies?

To answer this question, I employ a multi-country general equilibrium model, in which the Hukou system is modeled as a distortion to China's labor market. With data from 46 countries, the model is calibrated to bilateral trade flows, sectoral employment shares, and relative GDP per capita. Based on the calibrated model, counterfactual exercises are performed to evaluate the potential impacts of removing the Hukou system on China's economy as well as other economies in the world.

The model in this essay is based on the multi-country Ricardian trade model in Chapter 3. To allow for cross-country differences in sectoral composition, each economy in the model has three sectors: agriculture, manufacturing, and service. Subject to "iceberg" trade costs, countries are allowed to trade agricultural goods and manufactured goods. To generate cross-country differences in agricultural employment shares as observed in the data, there is a subsistence requirement for agricultural goods. Moreover, workers who work in agriculture also have access to a home production technology, which produces non-tradeable agricultural goods and is uniform across countries. This is to account for the fact that a significant portion of low income countries' agricultural labor engages in subsistence farming.

In the model, except for China, workers in all countries can move freely and costlessly across sectors. To model the impact of the Hukou system as a distortion to China's labor market, I follow the approach of Restuccia et al (2008) by assuming that Chinese workers face a cost of reallocating from agriculture to non-agriculture. This barrier to labor movement in China is modeled as a percentage of the wage rate in non-agriculture in China. As a result, the Hukou system depresses the income of agricultural workers in China and creates a wedge between the earnings of working in agriculture and non-agriculture for Chinese workers.

Calibration of the model mimics the exercise in Chapter 3. Specifically, for a sample of 46 countries, the model is calibrated to observed bilateral trade flows, sectoral employment shares, and relative real GDP per capita. As part of this calibration procedure, the cost of reallocating Chinese workers from agriculture to non-agriculture is calibrated to match the observed income differences between China's agriculture and non-agriculture sectors.

The calibration exercise also discusses the quantitative importance of introducing a cost to labor movement in China on accounting for two key moments in the data: the observed sectoral income differences and sectoral employment shares in China. In the calibrated model *without* barriers to labor movement in China, I show that there exist large discrepancies between the data and the model's predictions on agricultural employment share and the difference between agricultural income and non-agricultural income in China. This suggests that that there exist severe labor market distortions that depress agricultural income in China.

Based on the calibrated benchmark economy, counterfactual exercises are performed to evaluate the impacts of removing the Hukou system in China. Following Whalley and Zhang (2007), I attribute the entire differences in sectoral income in China to the Hukou system. Therefore, the removal of Hukou entails setting the cost of reallocating China's labor from agriculture to non-agriculture to zero. I find that it results in about 4.7% increase in China's per capita income. The increase in China's income is driven by 10.9% of its labor force being reallocated from agriculture to non-agriculture, which decreases China's wage rate in non-agriculture by 30.6% and increases its real manufacturing exports by 30.2%.

The removal of Hukou also affects the rest of the world in two ways. First, the increase in China's manufacturing exports lead other economies to reallocate their labor both within manufacturing and between manufacturing and non-manufacturing. This results in increases in manufacturing productivity and benefits all countries. Second, the decrease in the price of China's manufactured goods also impacts the relative prices of tradeable manufactured goods to agricultural goods in the world. As manufactured goods become cheaper relative to agricultural goods around the world, net agricultural exporters such as Thailand benefit and net agricultural importers such as Bangladesh are adversely impacted.

Overall, while the removal of the Hukou system had modest impacts on most sample countries (less than $\pm$ 1%), three of China's small neighboring economies have substantial *decreases* in their real income level. Namely, the reductions in real income per capita are 2.7% for Bangladesh, 3.2% for Sri Lanka, and 4.1% for Vietnam. On the other hand, Thailand's GDP increases by about 3.8%.

This asymmetry in the quantitative impacts of removing the Hukou system is driven by two factors. First, the impact of removing Hukou is highly correlated with a country's distance to China. In particular, the closer a country is to China, the larger the impact of removing Hukou tends to be. This is because, as trade costs increase as a country is further away from China geographically, it tends to trade less with China. As a result, these countries are less impacted by the changes in China's sectoral wages and the prices of China's tradeable goods.

Second, the impact of removing Hukou tends to be smaller when a county's economy is larger relative to that of China's. This is because the bilateral trade volume with China as share of a country's GDP tends to be smaller as the size of the country's economy increases. Therefore, the importance of its trade with China is inversely related to the size of a country's economy. Due to these two factors, the most impacted economies by the removal of Hukou are the four China's small neighboring countries: Thailand, Bangladesh, Sri Lanka, and Vietnam.

This essay is closely related to a large literature on China's Hukou system. Cai et al (2002), Zhu (2002), Fleisher and Yang (2003), Liu (2005), and Whalley and Zhang (2007) assess the impact of the Hukou system on China's growing income inequality. These papers all employ closed-economy frameworks and, as a result, their analysis is limited to Hukou's impacts within China. This essay differs by adopting an open economy approach and thus adds to the existing literature the possible impact of Hukou on both China and, through trade, other countries' income levels.

This essay is also related to the literature of distortions in factor markets, particularly factor markets in agriculture. Recent studies such as Gollin et al (2007), Restuccia et al (2008), Lagakos and Waugh (2010), and Tombe (2010) explore how distortions in the agriculture sector impacts a country's overall income and development. Except for Tombe (2010), these studies are based on close-economy frameworks and focused on how a country's factor market distortion impacts *its own* economy. Although it incorporates distortions to labor market in the Eaton-Kortum trade model, Tombe (2010) does not explore the possible economic effects of removing factor market distortions on other countries. This essay adds to the existing literature by providing a case study on the possible effects of reforming a country's factor market distortion - the Hukou system in China - on *both* its own economy and the rest of the world.

Another related literature is the literature of structural transformation. Studies in this literature, for instance, Laitner (2000), Caselli and Coleman (2001), Duarte and Restuccia (2010) have examined the role of sectoral changes in a country's overall economic performance. This essay shows that removing the Hukou system will result in large sectoral reallocation in China and significant sectoral reallocation for some countries in the world. Moreover, as a result of the sectoral allocation, the income levels of these countries are affected.

The rest of the essay is organized as follows. Section 4.2 describes the model used in this essay. Section 4.3 calibrates the model and discusses the quantitative implications of the labor market distortion in China. Section 4.4 performs the counterfactual where the Hukou system is removed. Section 4.5 discusses the robustness and sensitivity of the results of baseline counterfactual exercise. Section 4.6 concludes.

4.2 The Model

The model in this essay extends the multi-country and multi-sector general equilibrium model developed in Chapter 3 by introducing a distortion to China's labor market.[2] The model in Chapter 3 introduces three key features into the Eaton-Kortum Ricardian trade model. First, in order to consider agricultural production and agricultural trade, an explicit tradeable agriculture sector is added. Second, to capture subsistence intake of food, minimum consumption of agricultural goods is added to the consumer's preference. Last, to account for the fact that a significant portion of poor countries' labor in agriculture engages in subsistence farming, home production technology is introduced into agricultural production.

The world economy consists of n countries. Each country i has a measure of L_i workers. Labor is mobile across sectors, but immobile across countries. Within each country there are three sectors: agriculture, manufacturing, and service. All variables are normalized relative to country i's number of workers L_i.

[2] The distortion to China's labor market is the *only* difference between the current model and the one in Chapter 3. Therefore, this model section is largely a reproduction of Section 3.3 in Chapter 3. For readers who are already familiar with the earlier model, Section 4.2.4 in this essay is what sets the current model apart from the model in Chapter 3.

4.2.1 Production

Tradeable Sectors

Within country i, there are two tradeable sectors: agriculture (a) and manufacturing (m). A continuum of intermediate goods, indexed by $x^a, x^m \in [0,1]$, exist in each tradeable sector. The productions of intermediate agricultural good $q_i^a(x^a)$ and intermediate manufactured good $q_i^m(x^m)$ are given by:

$$\begin{aligned} q_i^a(x^a) &= z_i(x^a)^{-\theta^a}[s_i^a(x^a)]^{\gamma^a}[Q_i^a(x^a)]^{1-\gamma^a}, \\ q_i^m(x^m) &= z_i(x^m)^{-\theta^m}[s_i^m(x^m)]^{\gamma^m}[Q_i^m(x^m)]^{1-\gamma^m}, \end{aligned}$$

where $z(x^a)^{-\theta^a}$ and $z(x^m)^{-\theta^m}$ are the productivities used in producing goods x^a and x^m. $s_i^a(x^a)$ and $s_i^m(x^m)$ denote shares of labor used to produce these two goods. Similarly, $Q_i^a(x^a)$ and $Q_i^m(x^m)$ are the aggregate agricultural goods and manufactured goods used in producing x^a and x^m. It is assumed that $0 < \gamma^a, \gamma^m < 1$, and θ^a and θ^m are the same across countries, i.e. both parameters are sector-specific but not country-specific.

Aggregate agricultural goods and aggregate manufactured goods are simple aggregates of intermediate goods and are used as both intermediate inputs and final consumption goods:

$$\begin{aligned} Q_i^a &= \left[\int_0^\infty q_i^a(x^a)^{1-1/\eta}\phi(x^a)dx^a\right]^{\eta/(\eta-1)}, \\ Q_i^m &= \left[\int_0^\infty q_i^m(x^m)^{1-1/\eta}\phi(x^m)dx^m\right]^{\eta/(\eta-1)}. \end{aligned}$$

As in Eaton and Kortum (2002), productivities x_i^a and x_i^m are assumed to be random variables which have a density function that is exponential with parameters λ_i^a and λ_i^m. Productivities x_i^a and x_i^m are then amplified by the parameters θ^a and θ^m, which control the variability of x_i^a and x_i^m. The larger the θ^a or θ^m, the more dispersed these productivities are distributed in their respective sectors.

Non-tradeable Sector

The service sector produces a homogenous non-tradeable good. Its production is given by:

$$y_i^s = (\lambda_i^s)^{-1} s_i^s \,,$$

where s_i^s is the share of labor devoted to producing service, and $(\lambda_i^s)^{-1}$ is country i's productivity in service.

Home Production

In addition to the agricultural production described in Section 4.2.1, workers in the agriculture sector also have access to a "non-market" technology, termed home production. It is assumed that home production produces aggregate agricultural goods only, and the goods it produces are non-tradeable and only for final consumption. Its production is given by:

$$Q_i^{a,h} = A(s_i^{a,h})^\delta \,,$$

where $s_i^{a,h}$ is the share of labor devoted to producing home production, and A is the productivity of the home production technology. It is assumed that A is the same across countries, and workers cannot access A unless they work in the agriculture sector.

The addition of home production has two purposes. First, it captures the idea that a significant portion of poor countries' labor in agriculture engages in subsistence farming. These agricultural goods are consumed immediately and are not part of the market economy. Second, it enables the model to quantitatively account for cross-country differences in agricultural employment shares.

4.2.2 International Trade

Only intermediate agricultural goods $q_i^a(x^a)$ and intermediate manufactured goods $q_i^m(x^m)$ are tradeable. Trade costs are assumed to be "iceberg" trade costs, which are the same within sectors, but different across sectors. Respectively, let τ_{ij}^a and τ_{ij}^m be the trade costs on intermediate agricultural goods and intermediate manufactured goods, from country j to country i. It is assumed that $\tau_{ij} > 1$ for $j \neq i$ and $\tau_{ii} = 1$ for all i, as well as that it obeys the triangle inequality: $\tau_{ij} \leq \tau_{ik}\tau_{kj}$ for all i, j, k.

When countries in the model are open to international trade, the producer that delivers the lowest price in country i for $q^a(x^a)$ or $q^m(x^m)$ captures the market for that particular good:

$$\begin{aligned} p_i^a(x^a) &= \min\{p_{ij}^a(x^a) : j = 1, ..., n\} \\ p_i^m(x^m) &= \min\{p_{ij}^m(x^m) : j = 1, ..., n\} \ . \end{aligned}$$

Let w_i^a and w_i^m be the wage rates in agriculture and manufacturing in country i. Also denote P_i^a and P_i^m as the prices of aggregate agricultural good and aggregate manufactured good in i. Given the constant-return technology of producing intermediate goods $q_j^a(x^a)$ and $q_j^m(x^m)$, it is straightforward to show that

$$\begin{aligned} p_{ij}^a(x^a) &= (x^a)^{\theta^a}(w_j^a)^{\gamma^a}(P_j^a)^{1-\gamma^a}\tau_{ij}^a \\ p_{ij}^m(x^m) &= (x^m)^{\theta^m}(w_j^m)^{\gamma^m}(P_j^m)^{1-\gamma^m}\tau_{ij}^m. \end{aligned}$$

By making use of the properties of the extreme value distribution, one can show that the prices of the aggregate agricultural goods and manufactured goods are:

$$P_i^a = \Upsilon\Bigg[\sum_{j=1}^{n}\left[(w_j^a)^{\gamma^a}(P_j^a)^{1-\gamma^a}\tau_{ij}^a\right]^{-1/\theta^a}\lambda_j^a\Bigg]^{-\theta^a} \quad (4.1)$$

$$P_i^m = \Upsilon\Bigg[\sum_{j=1}^{n}\left[(w_j^m)^{\gamma^m}(P_j^m)^{1-\gamma^m}\tau_{ij}^m\right]^{-1/\theta^m}\lambda_j^m\Bigg]^{-\theta^m}, \quad (4.2)$$

where Υ is a collection of constants.[3] Let D_{ij}^a and D_{ij}^m be country j's share of country i's total spending on agricultural goods and manufactured goods. One

[3] See Alvarez and Lucas (2007) for a detailed derivation.

can show that:

$$D_{ij}^a = \frac{\left[(w_j^a)^{\gamma^a}(P_j^a)^{1-\gamma^a}\tau_{ij}^a\right]^{-1/\theta^a}\lambda_j^a}{\sum_{k=1}^n\left[(w_k^a)^{\gamma^a}(P_k^a)^{1-\gamma^a}\tau_{ik}^a\right]^{-1/\theta^a}\lambda_k^a} \tag{4.3}$$

$$D_{ij}^m = \frac{\left[(w_j^m)^{\gamma^m}(P_j^m)^{1-\gamma^m}\tau_{ij}^m\right]^{-1/\theta^m}\lambda_j^m}{\sum_{k=1}^n\left[(w_k^m)^{\gamma^m}(P_k^m)^{1-\gamma^m}\tau_{ik}^m\right]^{-1/\theta^m}\lambda_k^m} . \tag{4.4}$$

4.2.3 Household Budget Constraint and Preference

Each worker is endowed with one unit of labor, which she supplies inelastically. She faces the following budget constraint:

$$w_a s_i^a + w_m s_i^m + w_s s_i^s = P_i^a c_i^a + P_i^m c_i^m + P_i^s c_i^s ,$$

where w_i^s denotes the wage rate in country i's service sector, and s_i^a and s_i^m denote the shares of a worker's time in the tradeable agriculture and manufacturing sector. Therefore, a worker derives her income from working in the tradeable agriculture and manufacturing sectors, as well as the non-tradeable service sector. Subject to her budget, each worker chooses the consumption of agricultural good c_a, manufactured good c_m, and service good c_s to maximize her utility.

The utility function of a worker is:

$$U = \Omega \log(c_a - \bar{a}) + (1-\Omega)\log(c_m^{\beta} c_s^{1-\beta}) .$$

$\bar{a}$ is the term that represents subsistence needs of agricultural goods. Only after each worker consumes $\bar{a}$, she will spend the rest of her income on the three goods. Specifically, she spends a fixed fraction Ω of her after-subsistence income on agricultural goods (in addition to those for subsistence), a fraction $\beta(1-\Omega)$ on manufactured goods, and a fraction $(1-\beta)(1-\Omega)$ on service goods.

4.2.4 Labor Mobility and the Hukou System in China

Except for China, labor is assumed to be mobile across sectors in country i.

There is substantial support for the view that the Hukou system is a significant impediment to labor movement from agriculture to non-agriculture in China. To model this distortion, I follow the approach of Restuccia et al (2008) and assume that workers in China face a cost of reallocating from agriculture to non-agriculture. This cost is manifested in the parameter ψ, which is modeled as a percentage of the wage rate in non-agriculture. Given ψ, the Hukou system creates a wedge between the return of working in agriculture and working in non-agriculture in China.[4]

4.2.5 Equilibrium

Wage Rates Given that $s_i^{a,h}$ denotes the share of a worker's time in home production, the sum of s_i^a and $s_i^{a,h}$ is the share of a worker's time in agriculture.

Since workers can move freely across sectors (except for China), in equilibrium workers must be indifferent between working in each sector. Therefore

[4]See equation (4.8) for a mathematical representation of the effects of ψ.

the manufacturing wage is the same as the service sector wage in equilibrium:

$$w_i^m = w_i^s \,. \tag{4.5}$$

In equilibrium, marginal returns from labor in manufacturing are the same as in agriculture. While the return of one unit of labor in manufacturing is simply w_i^m, the return in agriculture is the sum of returns from working in the tradeable agriculture sector and home production. Equating the marginal returns from these two sectors yields the following equilibrium conditions (See Appendix A for a detailed derivation):

$$w_i^m = w_i^a + (1-\delta)(P_i^a A)^{\frac{1}{1-\delta}}(w_i^a)^{\frac{\delta}{\delta-1}} \,, \tag{4.6}$$

$$s_i^{a,h} = \left(\frac{\delta A P_h^a}{w_i^a}\right)^{\frac{1}{1-\delta}} \,. \tag{4.7}$$

Equations (4.5), (4.6), and (4.7) are derived under the assumption that workers can move freely and costlessly across sectors. This is not the case for China. Given ψ and in the context of the model, while (4.5) and (4.7) are unchanged, for China (4.6) becomes

$$(1-\psi)w^m = w^a + (1-\delta)(P^a A)^{\frac{1}{1-\delta}}(w^a)^{\frac{\delta}{\delta-1}} \,. \tag{4.8}$$

Labor Market Define variable $\bar{a}_i^{'}$ as $\bar{a}_i^{'} = \bar{a} - A(s_i^{a,h})^{\delta}$. $\bar{a}_i^{'}$ is the part of the subsistence of agricultural goods that is not produced by home production. Define W_i as $W_i = w_i^a s_i^a + w_i^m s_i^m + w_i^s s_i^s - P_i^a \bar{a}_i^{'}$. W_i is a worker's income after subtracting her spending on meeting subsistence.

In country i, total demand for service is $(1-\Omega)(1-\beta)W_i L_i$. Since labor is the only input used in producing service goods, the equilibrium condition for the service sector is:

$$w_i^s L_i s_i^s = (1-\Omega)(1-\beta)W_i L_i \,. \tag{4.9}$$

For the manufacturing sector, let X_k^m denote country k's total spending on manufactured goods. Country i's manufacturing labor income is equal to labor's share γ^m of country i's manufacturing exports to the world, including home sales:

$$w_i^m L_i s_i^m = \gamma^m \sum_{k=1}^{n} D_{ki}^m X_k^m \,. \tag{4.10}$$

X_k^m has two parts: demand for manufacturing goods as intermediate inputs and demand for final consumption:

$$X_k^m = \frac{1-\gamma^m}{\gamma^m} w_k^m L_k s_k^m + (1-\Omega)\beta W_k L_k \,.$$

Therefore from equation (4.10) we have:

$$w_i^m L_i s_i^m = \sum_{k=1}^{n} D_{ki}^m L_k \big[(1-\gamma^m) w_k^m s_k^m + \gamma^m (1-\Omega)\beta W_k\big] \,. \tag{4.11}$$

Similarly, given that a worker's demand for agricultural goods is $P_k^a \bar{a}_i^{'} + \Omega W_k$, for agriculture we have:

$$w_i^a L_i s_i^a = \sum_{k=1}^{n} D_{ki}^a L_k \big[(1-\gamma^a) w_k^a s_k^a + \gamma^a (P_k^a \bar{a}_i^{'} + \Omega W_k)\big] \,. \tag{4.12}$$

Finally, the market clearing condition for the labor market is:

$$s_i^a + s_i^{a,h} + s_i^m + s_i^s = 1 \,. \tag{4.13}$$

An equilibrium of the model is characterized by equations (4.5) - (4.9) and (4.11) - (4.13). To solve for an equilibrium of the model is to solve for equilibrium wage rates w_i^a, w_i^m, and w_i^s, as well as equilibrium labor shares $s_i^{a,h}$, s_i^a, s_i^m, and s_i^s.

4.3 Calibration and Parameterization

This section has three parts. The first part details the calibration of the model, which mimics the exercise in Chapter 3. The general strategy of the calibration procedure is to simulate the model to match key moments in the data. This essay differs from Chapter 3 in that, because of the Hukou system, the calibration exercise in this essay targets one more moment in the data. The second part discusses the calibrated benchmark economy which, overall, matches the key moments in the data reasonably well. The third part discusses the estimated distortion to China's labor market and its implications.

Calibration of the model is based on the same data as in Chapter 3. For a sample of 46 countries, the main targeted moments in the data are bilateral trade flows, sectoral employment shares, and relative GDP per capita.

4.3.1 Calibrating the Model

Calibration of the model proceeds in three steps. First, structural gravity equations implied by the model are used to estimate sectoral trade cost and the variation of agricultural productivity. Since the underlying structural gravity equations are the same and that the estimations are based on the same data, the values of the estimated parameters are $\theta^a = 0.21$, $\theta^m = 0.18$, and the values of sectoral trade cost can be found in Table 2.4.

The second and third steps of the calibration follow Chapter 3, where parameters of preferences and technology are calibrated to match observed sectoral employment shares and relative GDP per capita. The calibration exercise in this essay differs from that in Chapter 3 in two ways. First, since the model now includes a distortion to China's labor market, an additional moment in the data is needed to calibrate the parameter ψ. I target the ratio of agricultural income to non-agricultural income in the data. Drawing on data from the Rural and Urban Household Survey collected by China State Statistical Bureau, Fleisher and Yang (2003) estimate that the ratio of agricultural income per capita to non-agricultural income per capita was about 0.48 in China in 1997. To derive this value, the authors include home production in agricultural income and account for differences in price levels so that the reported number is in real term. These two measures ensure that the observed income ratio is an appropriate target for the current study and yields a value of 0.55 for ψ.[5]

Second, the values of the calibrated parameters differ from those in Chapter 3. This is because in the current model there exists a barrier to labor movement in China, which creates a gap between the wage rates in agriculture and

[5]See Section 4.3.3 and 4.5 for detailed discussions on the robustness of this calibrated parameter ψ and its implications on the results of counterfactual exercises.

non-agriculture that is absent from Chapter 3. As a result, the agricultural wage rate is lower in China in the current model because of the Hukou system. Since China trades with the rest of world and that the different Chinese labor income will affect its demand for tradeable goods from the rest of the world, the calibrated wage rates for *all* countries differ from those in Chapter 3. Given that the level of a country's labor income affects the values of all preference and technology parameters in the model, they are also different in the two studies.

Table 4.1 reports the new calibrated values in this essay. A comparison of Table 4.1 to Table 3.1 in Chapter 3 shows that the two studies have very similar values for the model parameters, with the largest difference being less than 10%. This indicates that the addition of China's Hukou system does not significantly alter the model's parameter values.

4.3.2 Calibrated Benchmark Economy

This section discusses how well the calibrated benchmark economy fits the data. Key moments for the model to match include bilateral trade flows, sectoral input and output shares, and cross-country income differences. In general, the benchmark economy matches the data reasonably well.[6]

In Figure 4.1 and 4.2, respectively, the predicted bilateral trade flows on

[6]There is no need to discuss how the calibrated economy matches relative GDP per capita observed in the data. This is because, in the third step of the calibration exercise, service sector productivity are calibrated to match *exactly* the observed GDP per capita.

agricultural goods and manufactured goods are plotted against the actual observed bilateral trade flows. One can see that for both tradeable goods the predicted observations provided by the benchmark economy are close to the data. I also calculate the R^2 statistics of the fit: they are 0.99 and 0.91 for agricultural trade flows and manufacturing trade flows.

In terms of measured agricultural output and agricultural employment shares, the calibrated benchmark economy also does reasonably well at fitting the data.[7] Figure 4.3 and 4.4 compare the two sets of moments in the calibrated economy to those in the data. One can see that most observations are clustered around the forty-five degree line. The R^2 statistics of the fit are 0.79 for agricultural output and 0.71 for agricultural employment share. For agricultural output share, the calibrated economy overestimates that of Vietnam by about 50% (0.30 in the data and 0.59 in the calibrated economy) and underestimates that of Columbia by about 45% (0.33 in the data and 0.18 in the calibrated economy). For agricultural employment share, the calibrated economy underestimates that of Zambia by about 69% (0.33 in the data and 0.71 in the calibrated economy).[8]

[7] It is called *measured* output shares since in the model there exists home production of agricultural goods. The output of this form of production does not enter the market economy and is not recorded by the official statistics. Therefore, to compare the calibrated economy to the data, I exclude home production in calculating agricultural output shares.

[8] Given the much larger number of targets in the data compared to the number of parameters in the model, it is difficult for the calibrated economy to closely match *all* countries' output and employment shares. Specifically, in the model, sectoral output and employment shares are largely determined by five parameters: two for home production, and three for preference parameters. However, for a sample of 46 countries, there are 92 observations to fit: 46 for output shares and 44 for employment shares.

4.3.3 How Significant Is China's Labor Market Distortion?

The key premise of this essay is that the Hukou system is largely responsible for the significant distortion to China's labor market. This view is consistent with a number of studies on the Hukou system in China. For example, Whalley and Zhang (2007) attribute the entire rural-urban income gap to the Hukou system and study the quantitative effects of its removal on reducing income inequality in China. Liu (2005) empirically studies the Hukou system and finds that the value of a Hukou ranges from more than 6 years to 16 years of annual income to a rural worker.

In this study, one way to examine the assumption of the Hukou system is to see how would a calibrated model, *absent any distortions in the labor market*, perform when compared to the data. Since in the current model the effect of the Hukou system is manifested in the calibrated parameter $\psi = 0.55$, a model without barriers to labor movement in China corresponds to $\psi = 0$. Such a model is identical to the one in Chapter 3, where no labor market distortion exists for all countries.

Given that agricultural employment share and the ratio of agricultural income per capita to non-agricultural income per capita in China are directly affected by the value of ψ, I focus on these two moments. From Table 4.2, one can see that the predictions generated by the calibrated model in Chapter 3 with $\psi = 0$ differ significantly from the data. Specifically, it predicts that the ratio of agricultural income per capita to non-agricultural income per capita is

1.16 and that agricultural employment share is 35% in China, while they were 0.48 and 65% in 1997 in the data. On the other hand, the calibrated benchmark ($\psi = 0.55$) in this essay predicts that agricultural employment share is 53% and matches exactly the ratio of agricultural income per capita to non-agricultural income per capita in China.

The large discrepancy between the data and the model without barriers to labor movement in China is consistent with the view that there exist severe labor market distortions that depress agricultural income in China.

4.4 Counterfactual Exercises: Removing the Hukou System in China

In this section, I ask what are the possible effects of removing the Hukou system on both China and the rest of the world. In the counterfactual exercise used to answer this question, I assume that the *entire* distortion to China's labor market is due to the Hukou system. Therefore, in the context of the model, removing Hukou is equivalent to setting the parameter of China's labor market distortion ψ from 0.55 to 0. This approach is similar to Whalley and Zhang (2007), in which the authors assume the Hukou system is the sole cause of the income gaps between different sectors and regions in China.

Eliminating the Hukou system (setting $\psi = 0$) leads to significant improvement - about 4.7% - in China's real GDP per capita. This change in China's income is driven by the substantial labor movement and the large price changes in China. Specifically, about 10.9% of Chinese workers are reallocated from agriculture to non-agriculture. This amounts to more than 62 million workers moving from agriculture to manufacturing and about 23 million workers to service. As a result of this labor reallocation in China, world employment in manufacturing increases by about 22%. Moreover, the increase in China's manufacturing labor force decreases its manufacturing wage rate by 30.6%, and the relative price of agricultural to manufactured goods in China increases by 105%. As China's manufactured goods become significantly cheaper relative to agricultural goods, its real manufacturing exports increase by 30.2% and agricultural imports increase by 452%.

The removal of Hukou has implications not only for China's economy, but also the rest of the world. As Figure 4.5 shows, except for four China's small neighboring countries, the impacts are relatively small (less than $\pm 1\%$) for all other countries. Four economies - Thailand (THA), Bangladesh (BGD), Sri Lanka (LKA), and Vietnam (VNM) - are substantially impacted by the elimination of the Hukou system in China. The changes in real income per capita are 3.8% increase for Thailand and, respectively, 2.7%, 3.2%, 4.1% decrease for Bangladesh, Sri Lanka, and Vietnam.

Changes in other countries' income, as a result of the removal of the Hukou system, are due to two factors. First, all countries - except for China, which experiences a roughly 1.5% *decrease* - experience increases in manufacturing productivity. This is caused by the fact that, as Chinese manufacturing exports become more competitive in the world market, part of other economies' manufacturing production - both domestic and exports - is forced to discontinue due to China's cheaper manufacturing goods. As a result, these countries observe labor reallocation *both* within manufacturing and from manufacturing to non-manufacturing, which helps increase their average levels of efficiency in manufacturing. Table 4.3 documents the extend of the effects of this labor reallocation.

Second, as it causes a decrease in China's manufacturing prices, the removal of Hukou also decreases the relative prices of manufacturing goods worldwide, which is documented in Figure 4.6. While the average change is modest for most countries (about -4.4%), the decreases are more profound for those close to China geographically. For example, for countries that are less than 4,000 kilometers away from China, the average decrease in the relative price of manufactured goods is about 8.9%.[9] This terms of trade effect benefits net agricultural exporters and hurts net agricultural importers.

The combination of these two effects is such that agricultural exporters unequivocally benefit from the removal of Hukou. On the other hand, agricultural

[9]These countries include Vietnam, Japan, Bangladesh, Thailand, Korea, Sri Lanka, Malaysia, Philippine, India, and Indonesia.

importers may or may not gain, depending on which effect is larger quantitatively.

Among the four countries that are most impacted by the removal of Hukou, Thailand is a net exporter of agricultural goods while Bangladesh, Sri Lanka, and Vietnam are net importers of agricultural goods. However, their net sectoral trade positions can only partly explain the changes in their income levels. A closer look at Figure 4.5 and 4.6 reveals two factors that determine the *quantitative* impacts of the removal of Hukou.

First, the impacts of removing Hukou is highly correlated with each country's geographic proximity to China, as illustrated by Figure 4.6. This is not surprising since trade costs increase as bilateral distance from China increases. Therefore, a country that is close to China also tends to trade more with China. As a result, its economy will likely be more sensitive to the price and sectoral changes in China. For the four countries that experience substantial changes in income, they are all located in Southeast Asia and are very close to China geographically.

Second, holding other factors equal, the larger the size of an economy, the less the impact of removing Hukou tends to be. This relationship is shown in Figure 4.5. For example, although Korea and Japan have similar bilateral distance to China as Vietnam and Thailand, the impacts of removing Hukou are far more moderate for the first two countries. This is because the bilateral trade volumes with China as a share of Korea's and Japan's economy are smaller than that of Vietnam and Thailand. Therefore, Korea and Japan are less impacted by the removal of the Hukou system.

4.5 Sensitivity and Robustness

The baseline counterfactual exercise in Section 4.4 assumes that the Hukou system is responsible for the *entire* labor market distortion in China. In this section, I discuss the reasonableness of this assumption and how the results of counterfactual exercise vary when the Hukou system is only responsible for *part of* the labor market distortion in China.

4.5.1 How Much of China's Labor Market Distortion Is Due to the Hukou System?

Differences in many factors, such as average age, education level, and work experience between rural and urban residents, can also be causes of the income gap between agriculture and non-agriculture in China. Therefore, it is difficult to precisely pinpoint the quantitative role of Hukou in distorting China's labor market and contributing to the observed income gap in China. To address this concern, I refer to a study in the literature of Hukou that provides alternative measures of its effects and consider its implications on the results of the baseline counterfactual exercise in Section 4.4.

Given the large income differences between rural and urban residents observed in China, Liu (2005) attempts to measure how much the Hukou system is responsible for this income gap. Drawing on data from the Chinese Household Income Project 1995, the author estimates that the value of an urban Hukou to individuals in rural China ranges from 12,301 yuan to 30,853 yuan. This estimate is a *lifetime* value of Hukou and based on the assumption of an average of 25 years of working life.[10]

Since the analysis in this essay is based on yearly data, I first derive an estimate of the *annual* value of a Hukou. To do this, I assume a 5% annual discount rate and calculate the average annual value of Hukou.[11] This yields an estimate that ranges from 831 yuan to 2085 yuan.

According to the National Bureau of Statistics of China, in 1997 - the model year in this essay - the per capita annual net income of a rural household and an urban household were 1926 yuan and 4377 yuan. This means that the rural-urban income gap in China was 2451 yuan in 1997. Given my estimate of the annual value of a Hukou, its share of contribution to the rural-urban income gap ranges from 34% to 85%.

These estimates suggest that the baseline counterfactual exercise overestimates the effects of removing Hukou, as it assumes that the Hukou system contributes 100% to the observed sectoral income gap in China. To assess the potential bias of overestimating Hukou's contribution to the observed income

[10] Specifically, this estimate is based on a rural resident who is 40 years old and retires at 65.
[11] Let x be the annual value of Hukou. Then $x + \frac{x}{1.05} + \frac{x}{1.05^2} + ... + \frac{x}{1.05^{24}} = [12,301 \quad 30,853]$.

gap in China, I perform two counterfactual exercises where the Hukou system is assumed to be responsible for 34% and 85% of the rural-urban income gap in China.[12] Table 4.4 provides a summary of results of these two counterfactual exercises.

Assuming that the Hukou system is responsible for 34% - the lower bound of the estimated range, its removal will lead to 1.6% and 1.3% *increases* in real income for China and Thailand. It will also lead to 0.9%, 1.2%, and 1.4% *decreases* in real income for Bangladesh, Sri Lanka, and Vietnam. On the other hand, assuming that the Hukou system is responsible for 85% - the upper bound of the estimated range, its removal will lead to 4.0% and 3.3% *increases* in real income for China and Thailand. It will also lead to 2.3%, 3.0%, and 3.5% *decreases* in real income for Bangladesh, Sri Lanka, and Vietnam.

Given the above results, although the effects of removing Hukou may be overestimated, the main findings of the baseline counterfactual exercise in Section 4.4 still hold true. Namely, substantial changes in real income for China and its four neighboring countries could occur when the Hukou system is eliminated in China.

[12]In the baseline counterfactual exercise, with the assumption that the Hukou system contributes 100% to the income gap, $\psi = 0.55$ is reduced to 0. Therefore, if the Hukou system's contribution is 25%, it means in the counterfactual ψ is reduced from 0.55 to 0.4125 ($0.55 \times (1 - 0.25) = 0.4125$).

4.5.2 The Linearity of the Effects of Removing the Hukou System

Since Section 4.5.1 and Table 4.4 only report the potential impacts of removing Hukou when the its contribution is at the upper and lower bound of the estimated range, one does not know how the effects vary at points other than the maximum and minimum. To help answer this question, I explore the linearity of the effects of removing the Hukou system in China.

Having calculated the changes of sample countries' real income by assuming that the Hukou system contributes 25%, 50%, 75% to the observed income gap in China, it appears that the effects of removing Hukou are highly linear. To help illustrate this finding, Figure 4.7 shows the changes of per capita real income of China and the four countries that are most impacted by the removal of Hukou.

4.6 Conclusion

This essay contributes to the literature of China's Hukou system by evaluating the potential impacts of removing the Hukou system on not just China but also the rest of the world. It finds that, while removing the Hukou system increases China's income level significantly (about 4.7%), China's small neighboring economies will also be substantially impacted. For example, the decreases in real GDP per capita are 2.7%, 3.2%, and 4.1% for Bangladesh, Sri Lanka, and Vietnam, respectively. On the other hand, Thailand, stands to enjoy an 3.8% increase in its income. Three factors determine the extend of the removal of Hukou on each economy: its sectoral net trade position prior to the removal of Hukou, its geographic proximity to China, and the size of its economy relative to that of China's.

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Table 4.1: Values of parameters (with China's Hukou)

Parameter	Description	Value
θ^m	variation of technology in manufacturing	0.18
γ^a	share of value added in agriculture	0.41
γ^m	share of value added in manufacturing	0.33
δ	share of labor in home production	0.70
η	elasticity of substitution in aggregating intermediate agricultural goods and manufactured goods	2.0
Ω	share of income spent on agricultural goods after subsistence	0.0047
β	share of income spent on manufactured goods after consuming agricultural goods	0.25
$\bar{a}$	subsistence needs of agricultural goods	960
A	labor productivity of home production	1435
ψ	distortion of China's labor market	0.55

Table 4.2: A comparison of predictions of models with and without distortions to China's labor market

	Data	Model with labor distortion	Model without labor distortion
ag income to non-ag income	0.48	0.48	1.16
agricultural employment share	0.65	0.53	0.35

Table 4.3: Domestic shares of manufacturing production and changes manufacturing labor productivity after removing Hukou

Country	With Hukou share	Without Hukou share	Changes in man. labor productivity
Australia	0.95	0.93	1.80%
New Zealand	0.91	0.87	3.27%
China	0.96	0.99	-1.50%
Japan	0.98	0.97	0.73%
Korea	0.91	0.86	5.59%
Indonesia	0.93	0.90	2.60%
Malaysia	0.90	0.86	4.09%
Philippines	0.85	0.78	6.24%
Thailand	0.90	0.88	2.61%
Vietnam	0.73	0.58	20.7%
Bangladesh	0.86	0.81	5.21%
India	0.95	0.91	3.76%
Sri Lanka	0.76	0.71	7.20%
Canada	0.85	0.84	1.04%
United States	0.98	0.97	0.17%
Mexico	0.95	0.94	1.36%
Columbia	0.83	0.82	1.18%
Peru	0.91	0.89	1.79%
Venezuela	0.87	0.86	0.84%
Argentina	0.93	0.92	1.72%
Brazil	0.97	0.96	0.69%
Chile	0.85	0.80	1.61%
Uruguay	0.63	0.59	2.13%
Austria	0.68	0.68	0.68%
Belgium-Luxembourg	0.54	0.50	0.17%
Denmark	0.65	0.64	1.86%
Finland	0.79	0.78	1.78%
France	0.84	0.83	0.63%
Germany	0.88	0.87	0.27%
United Kingdom	0.84	0.83	0.90%
Greece	0.64	0.63	1.64%
Ireland	0.60	0.55	1.58%
Italy	0.90	0.89	0.36%
Netherlands	0.69	0.67	0.99%
Portugal	0.74	0.73	0.83%
Spain	0.85	0.84	0.76%
Sweden	0.81	0.80	0.65%
Switzerland	0.66	0.65	0.43%
Hungary	0.58	0.55	0.39%
Poland	0.71	0.69	1.38%
Turkey	0.79	0.77	1.37%

Table 4.3: Domestic shares of manufacturing production and changes manufacturing labor productivity after removing Hukou (continued)

Country	With Hukou share	Without Hukou share	Changes in man. labor productivity
Morocco	0.74	0.73	1.25%
Malawi	0.84	0.77	2.14%
Zambia	0.78	0.77	1.73%
Zimbabwe	0.80	0.76	2.12%
Uganda	0.81	0.77	3.90%

Table 4.4: Impacts of removing Hukou on select countries' GDP per capita

	Change of GDP per capita		
	Effects of Hukou = 34%	Effects of Hukou = 85%	Effects of Hukou = 100%
China	1.6%	4.0%	4.7%
Thailand	1.3%	3.3%	3.8%
Bangladesh	-0.9%	-2.3%	-2.7%
Sri Lanka	-1.2%	-3.0%	-3.2%
Vietnam	-1.4%	-3.5%	-4.1%

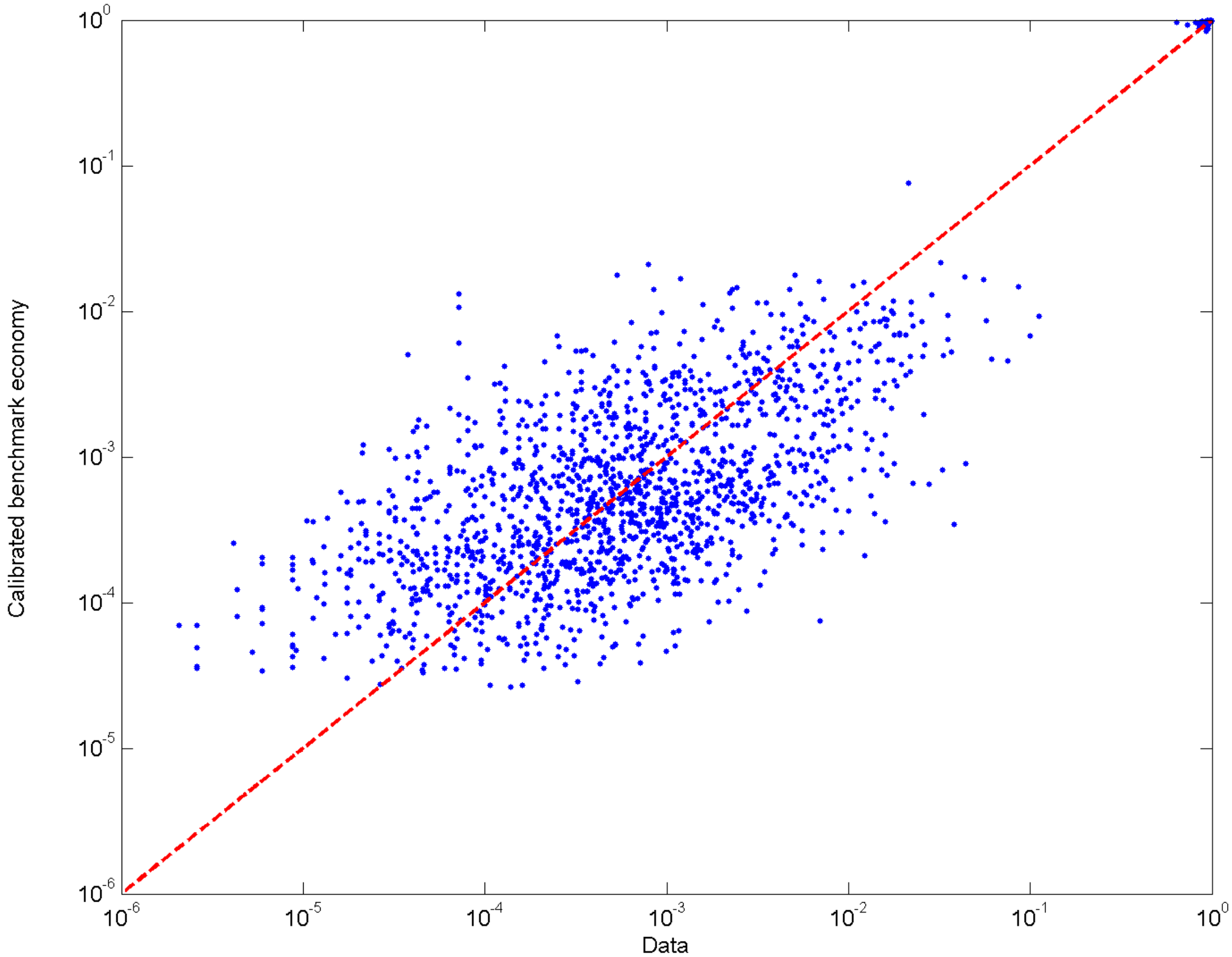

Figure 4.1: Bilateral agricultural trade flows: benchmark against data

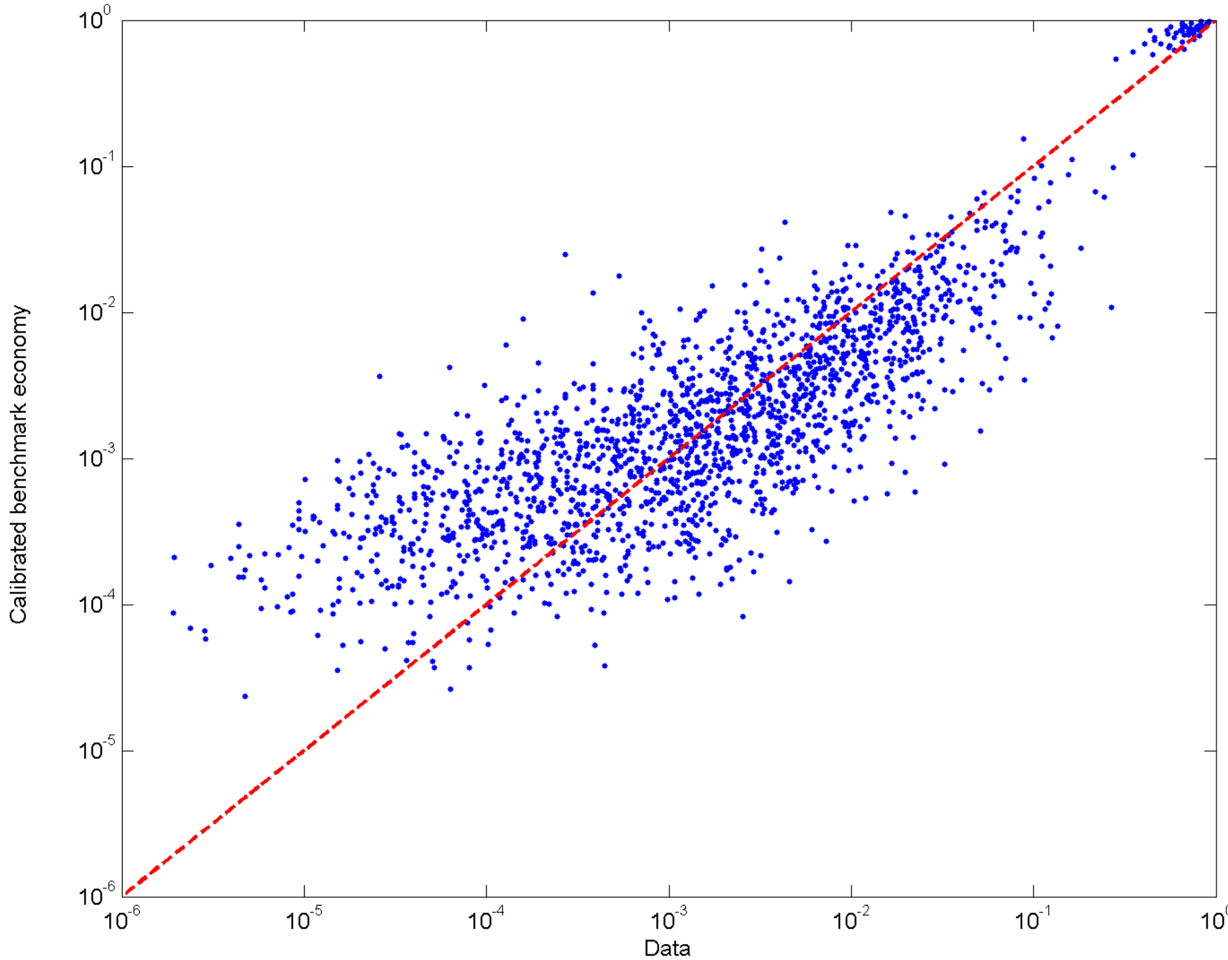

Figure 4.2: Bilateral manufacturing trade flows: benchmark against data

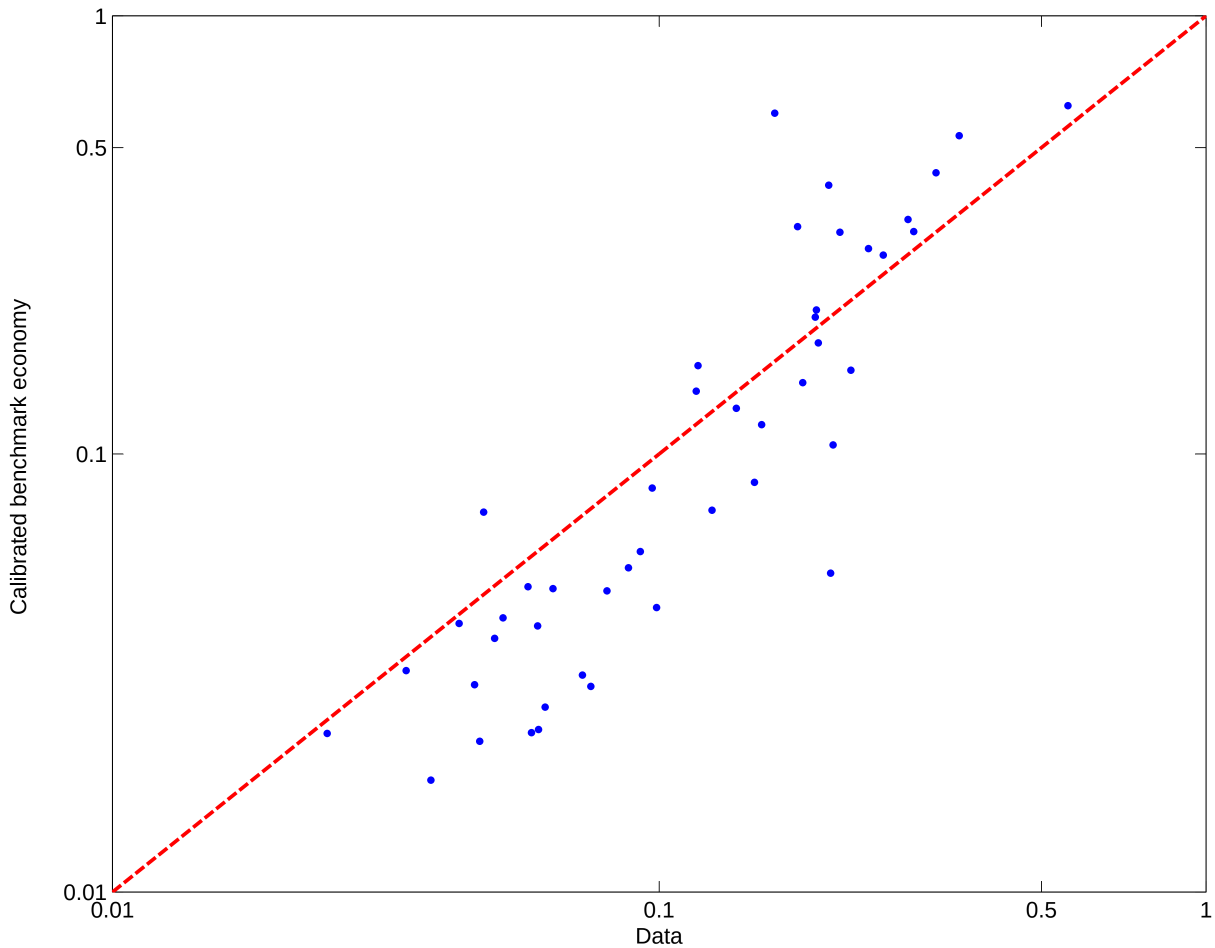

Figure 4.3: Measured agricultural output shares: benchmark against data

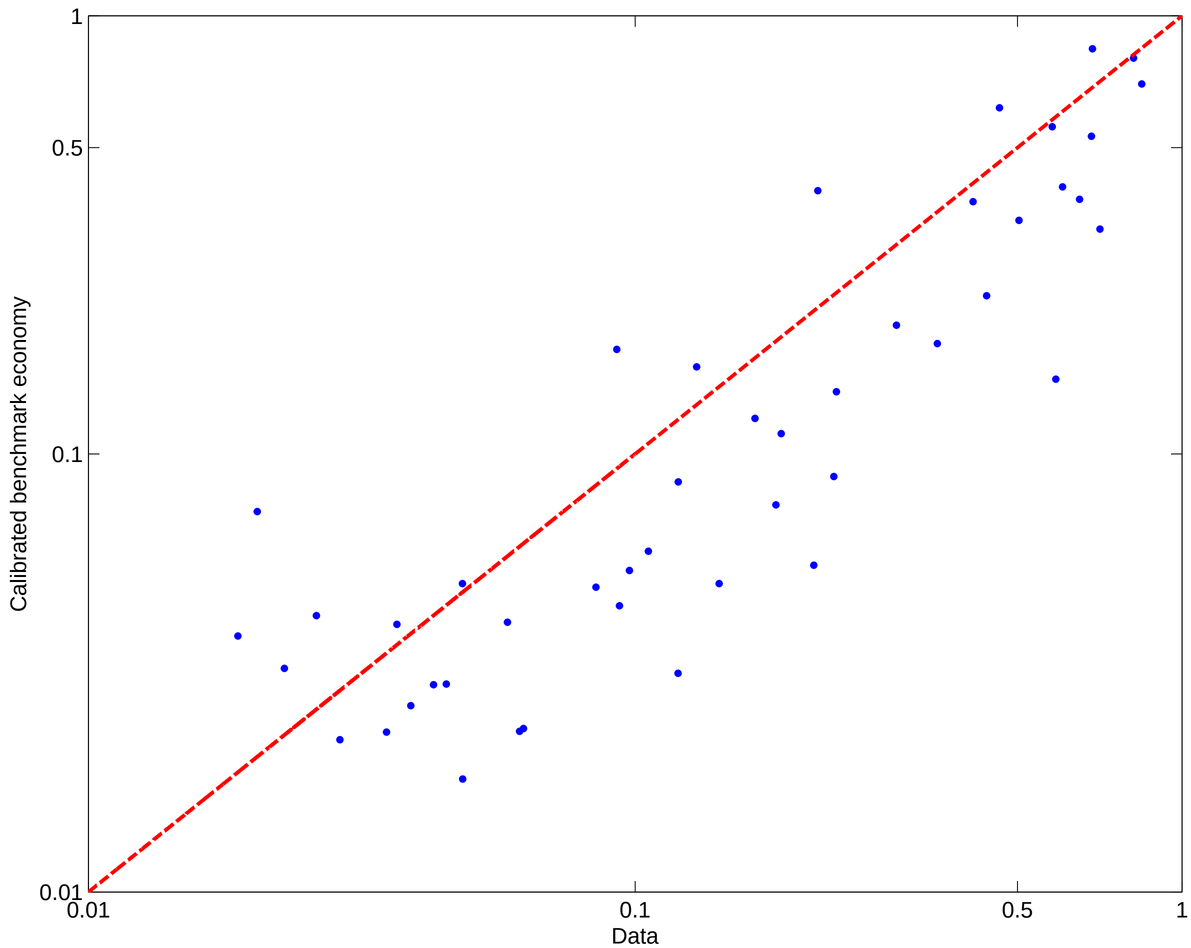

Figure 4.4: Agricultural employment shares: benchmark against data

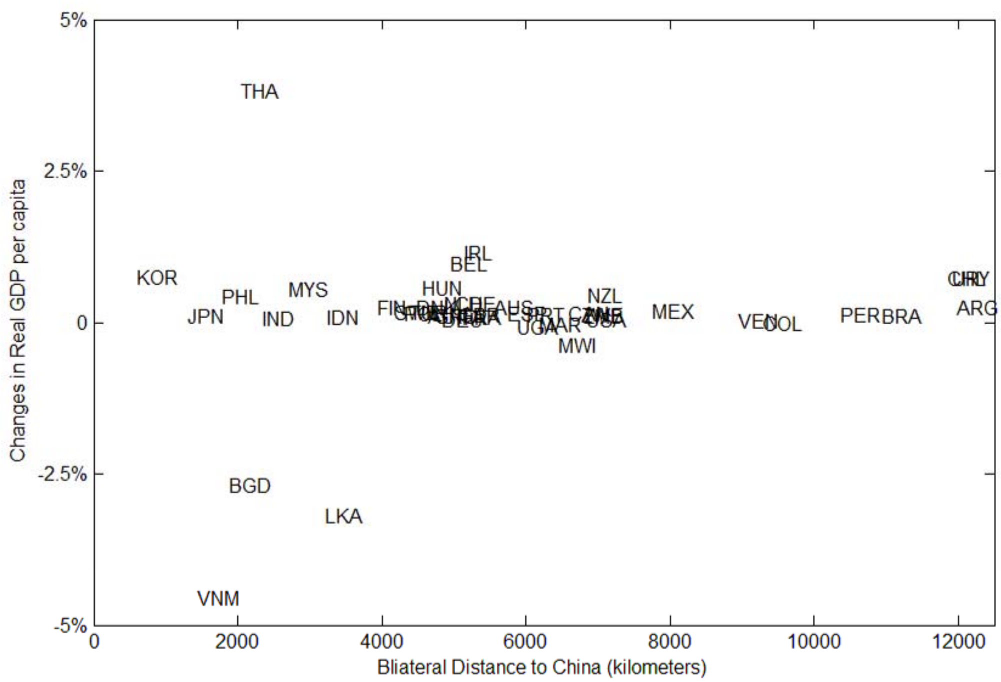

Figure 4.5: Changes in real GDP after removing Hukou

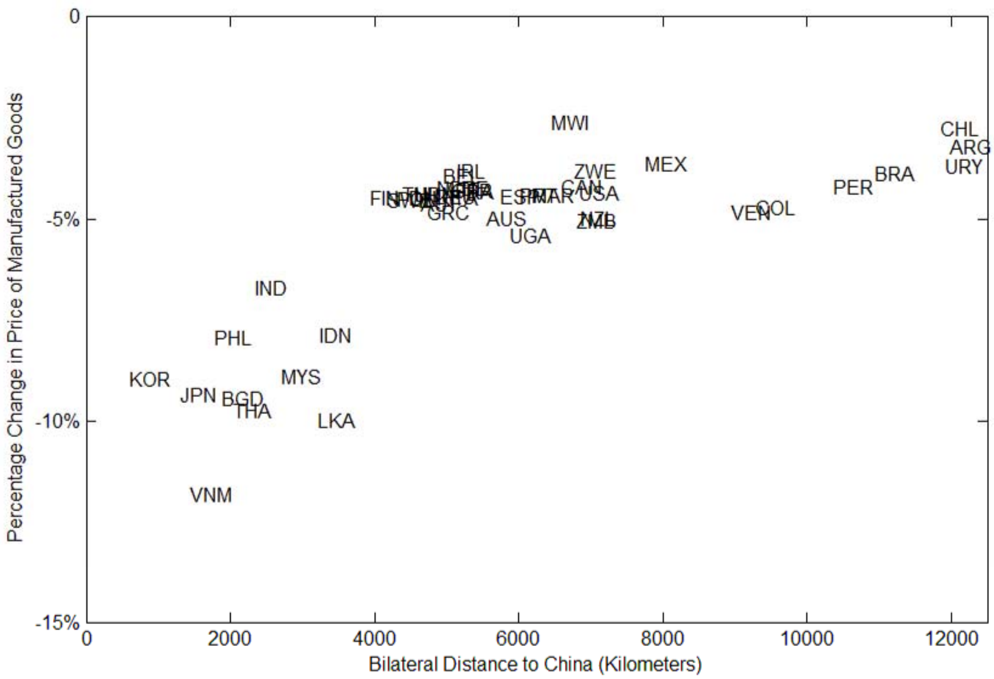

Figure 4.6: Changes in relative prices of manufactured goods after removing Hukou

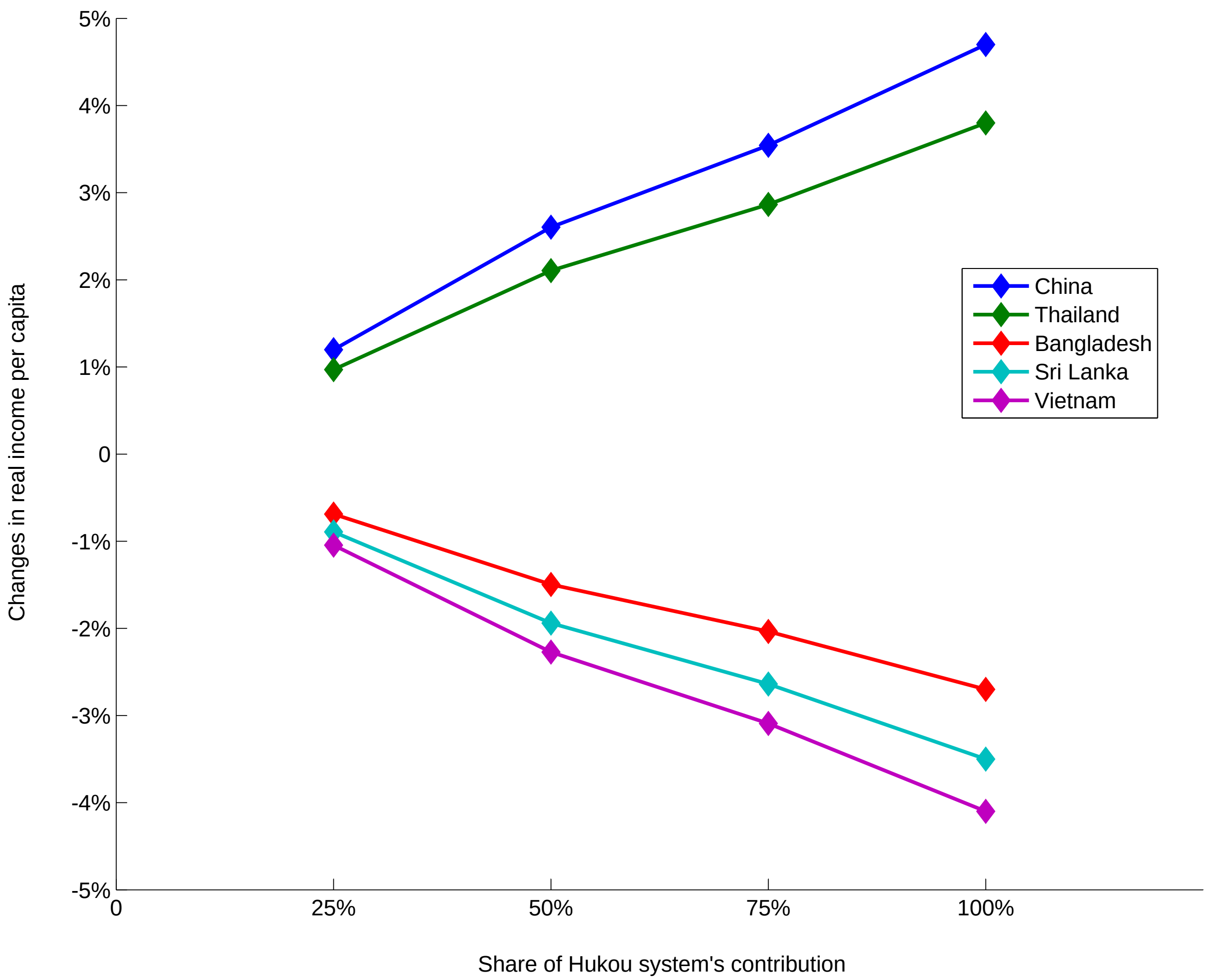

Figure 4.7: Changes in real income given different shares of Hukou's contribution

Chapter 5

Conclusion

This thesis makes several contributions to the international trade literature. In the first essay, I empirically estimate the causes of the observed low intensity of agricultural goods. The estimation is based on a robust methodo-logy where I derive and estimate structural equations from a Eaton-Kortum type trade model. I find that agricultural goods are traded less intensively than manufactured goods is largely due to high agricultural trade costs. I also find large productivity variation in agriculture across countries, which suggests that the degree of comparative advantage is high in agriculture and that there exist large unrealized gains from agricultural trade.

In the second essay, using a quantitative general equilibrium trade model, I show that potential gains from trade are substantial and much larger for poor countries when the food problem is present. Moreover, lowering trade costs on agricultural goods is the key to realizing these gains. Finally, when assessing gains from trade for poor countries, it is important to consider the quantitative effects of subsistence needs and home production of agricultural goods.

In the third essay, I evaluate the potential quantitative impacts of removing China's Hukou system on not just China's economy but also individual economies in the world. I find that, while removing the Hukou system increases China's income level significantly (about 4.7%), China's small neighboring economies will also be substantially impacted. For example, the decreases in real GDP per capita are 2.7%, 3.2%, and 4.1% for Bangladesh, Sri Lanka, and Vietnam. On the other hand, Thailand, stands to enjoy an 3.8% increase in its income. These results show that the sizes of China's population and its economy are large enough that a reform to its labor market will have implications on not only its own economy but also the rest of the world.

Appendix A

Deriving Equilibrium Wage Rate in Agriculture

When a worker devotes time in the agriculture sector, she has two choices: working in the market segment (receiving market wage rate w^a) or working in home production (no wage but is able to consume her own production). In equilibrium, the value of devoting an extra unit of labor in home production must be the same as working in the market segment. Let T_h devote the time spent on home production, we have:

$$\delta P^a A (T_h)^{\delta-1} = w^a \ .$$

Solving for T_h, we have:

$$T_h = \left(\frac{\delta A P^a}{w^a} \right)^{\frac{1}{1-\delta}} \tag{A.1}$$

Suppose the worker devotes one unit of labor in agriculture, her returns from labor is:

$$\begin{aligned} w^a(1-T_h) + P^a A (T_h)^{\delta} &= w^a + (1-\delta) P^a A (T_h)^{\delta} \\ &= w^a + (1-\delta)(P^a A)^{\frac{1}{1-\delta}} (w^a)^{\frac{\delta}{\delta-1}} \end{aligned} \tag{A.2}$$

Equations (A.1) and (A.2) provide two equilibrium conditions for the labor market in section 3.3.3.

Appendix B

Evidence and Measures of the Estimated Trade Costs

The estimated trade costs in this thesis are "broadly defined" trade costs and capture all costs associated with shipping a good from one country to the final user in another country. Examples of these costs include tariffs, quotas, shipping costs, distribution costs, language costs, and market entry costs. While it is infeasible to survey all components of the estimated trade costs, in this section I discuss some observable and measurable components of the trade costs on agricultural goods and manufactured goods and calculate their shares in the estimated trade costs in this thesis.

The first direct measures of trade costs are policy barriers on agricultural goods and manufactured goods. One set of measures of these policy barriers are reported in the GTAP data base, which compiles a wide range of trade policies such as tariffs, quotas, and the like, and calculates the ad valorem import tax rates for a sample of 77 countries. Therefore, it contains measures of tariff and some nontariff barriers to trade. According to the GTAP data base, the average import tax rate on agricultural goods is 24.5%, while those on manufactured goods is 7.9%. Given that the estimated trade costs in this essay range from 170% to 448% for agricultural goods, this means that policy barriers can account for at least 5.4% and as much as 14.4%. On the other hand, given that the estimated manufacturing trade costs range from 77% to 225%, this means that policy barriers can account for at least 3.5% and as much as 10.3%.

Another component of the estimated trade costs that can be measured is transport costs. Two main components of transport costs are international freight costs and local distribution costs. As Anderson and van Wincoop (2004) argue, since local distribution costs on *tradeable goods* vary greatly across countries and affect exporters' decisions, they should be included in the broadly defined trade costs, such as the ones in this thesis.

Based on 1994 data from 7 importing countries, Hummels (2001) reports that the average freight rates for a variety of goods. According to the study, for agricultural goods, the average freight rate ranges from 7.4% (Uruguay) to 21.6% (Argentina), with an average of 16.6% for the 7 sample countries. For manufactured goods, the average freight rate ranges from 7.9% (Uruguay) to 17.7% (Brazil), with an average of 13.2% for the 7 sample countries.

Compared to costs on international freights, the local wholesale and retail distribution costs on tradeable goods are much larger. Based on 1997 U.S. data, Burstein et al (2003) reports that the distribution costs for 6 agricultural products range from 54% (eggs) to 82% (fresh fruits), with an average of 69%. While distribution costs on manufactured goods are not reported, Burstein et al (2003) reports an average of 46.2% for *all* tradeable goods in U.S., which I will use as the distribution costs on manufactured goods.[1]

Combining international freight costs and distribution costs, one can calculate that transport costs account for at least 19.1% and as much as 50.4% of the estimated agricultural trade costs. On the other hand, transport costs account for at least 26.4% and as much as 77.1% of the estimated manufacturing trade costs.[2]

Another important but less-measurable component of trade costs is market entry costs. Examples of market entry costs include information costs, language costs, and legal costs that a firm incurs in order to sell its products in a foreign market. Most market entry costs are not directly observable and can only be inferred from the data. Yet existing estimates in the trade literature show that market entry costs are substantial. For example, using plant-level

[1] Distribution costs in poor countries are very likely to be higher than those in U.S.. See Adamopoulos (2011) for a discussion on how poor countries' lack of infrastructure contributes to their high distribution costs.

[2] Given that the difference between the estimated agricultural and manufacturing trade costs in this thesis ranges from 93% to 223%, one can calculate how much of the difference can be accounted for by the "measurable" components of the trade costs: in terms of policy barriers, the difference is 16.6% (agriculture - manufacture); in terms of international freight costs, it is 4.5%; in terms of distribution costs, it is 22.8%. Together, the difference is 43.9%.

panel data on three Colombian manufacturing industries, Das et al (2007) estimates that for a Columbian firm the average entry costs into a foreign market ranges from \$344,000 to \$477,000 U.S. dollars. These costs are significant considering that the average annual export volume of a Columbian firm is about \$1.87 million U.S. dollars. In other words, foreign market entry costs for a Columbian firm range from 18.3% to 25.5% of its annual foreign sales.

Currirculum Vitae

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