Trade, Migration and Productivity: A Quantitative Analysis of China

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Abstract

We study how misallocation due to goods- and labour-market frictions affect aggregate labour productivity in China. Combining unique data with a general equilibrium model of internal and international trade, and migration across regions and sectors, we quantify the magnitude and consequences of trade and migration costs. The costs were high in 2000, but declined afterward. The decline accounts for a third of the aggregate labour productivity growth in China between 2000 and 2005. Reductions in internal rather than international costs are particularly important. Despite the decline, migration costs are still high and potential gains from further reform are large.

JEL Classification: F1, F4, R1, O4

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1 Introduction

Differences in aggregate productivity are a key source of large cross-country income differences (Klenow and Rodriguez-Clare, 1997; Hall and Jones, 1999; Caselli, 2005) and misallocation of inputs can be an important reason for low levels of aggregate productivity in poor countries (Banerjee and Duflo, 2005; Restuccia and Rogerson, 2008; Hsieh and Klenow, 2009; Bartelsman et al., 2013). It is therefore important to understand the sources of misallocation. Indeed, in a review of the recent literature on misallocation, Restuccia and Rogerson (2013) state "the most persuasive evidence in support of the role of misallocation will come from work that follows the direct approach in specific contexts, especially those in which we observe changes in some underlying source of misallocation and can measure the resulting change in misallocation and aggregate TFP." In this paper we provide direct evidence on frictions to labour and goods flows across space and sectors as a source of misallocation in China. We further quantify the contribution of changes in these frictions to China's growth between 2000 and 2005. It is well known that China in the early 2000s had substantial policy-induced migration costs (Poncet, 2006; Cai et al., 2008) and internal trade costs (Young, 2000; Poncet, 2005). Since then, the Chinese government has undertaken policy reforms and infrastructure investments that reduced both migration and trade costs and, at the same time, the Chinese economy has experienced significant aggregate productivity growth (Zhu, 2012). China therefore provides an excellent case study for evaluating how much of aggregate productivity growth could be attributed to reductions in migration and trade costs and the resulting decrease in misallocation.

As a framework for our quantitative analysis, we develop a two-sector multi-region general equilibrium model featuring internal trade, international trade, and worker migration. Our model builds on the recent work of Ahlfeldt et al. (2012) and Redding (2015). Following Redding (2015), we introduce within-country trade and worker mobility into the Eaton and Kortum (2002) model and explicitly model worker location choices in the presence of migration costs. Our main departure from these papers is that we introduce frictions to both between-region and within-region-between-sector migration. Specifically, within each region there is an agricultural and a nonagricultural sector, workers are heterogeneous in their preferences regarding locations and sectors, and some workers migrate or switch sectors despite the costs while others do not. Even with these rich and realistic features, the model is still analytically tractable and can be easily implemented for quantitative analysis.

We fit this model to China, mapping it directly into the data for China's provinces and sectors, and the rest of the world in 2000. To estimate the changes in trade and migration costs, we use the model-implied gravity equations and unique data on trade and migration flows. Specifically, we use the 2002 and 2007 China Interregional Input-Output Tables, which provide the full bilateral trading matrices for all provinces and for a variety of sectors, and the 2000 Population Census and 2005 Population Mini Census, which provide information on migration between and within provinces.

Our estimates show that trade costs were large in 2002. But between 2002 and 2007, China's trade costs declined significantly: on average, internal costs fell by 10-15% and international costs fell by almost 10% in nonagriculture and nearly 25% in agriculture. For migration costs, we consider them ongoing *flow* costs rather than *sunk* costs due to the unique institutional feature of China. It has a *hukou* (household registration) system that imposes large costs on working and living outside one's *hukou* locaton, primarily through restricted access to social services and limited employment rights. These costs are recurring and exist as long as migrants do not have a local *hukou*. In addition, since all rural land and some urban land are collectively owned and there is a lack of rental mark for land, migrants who leave their *hukou* locaton also lose their access to returns from land. According to our estimates for 2000, the average cost of moving within a province but from rural to urban area is equivalent to shrink one's real income at destination by a factor of nearly 3; the costs of between-province migration are an order of magnitude higher. These costs are prohibitive for most workers, so only a small proportion of workers move–though the absolute number is large, most of them are young and their migration costs are much lower than the average. The focus of our analysis in this paper will be on the changes rather than the levels of migration costs. Between 2000 and 2005, we find that migration costs declined substantially – by 15% on average, and by as much as 40% for between-province moves.

What are the consequences of these measured changes in trade and migration costs? In a series of quantitative exercises using the fully calibrated model, we evaluate how cost changes affect trade flows, migration, aggregate labour productivity and welfare. We find that the reductions in trade costs can account for most of the the increases in China's internal and external trade between 2002 and 2007. They have little effect on migration, but large effects on aggregate labour productivity and welfare, both increase by more than 13%. Because most provinces in China trade more with other provinces of China than with the rest of the world, the internal trade cost reductions have much larger impact on the increases in these provinces's trade shares and the aggregate productivity growth and welfare than the external cost reductions have. Similarly, the masured changes in migration costs have little effect on trade shares, but large effects on migration and aggregate productivity and welfare. In response to the measured migration cost reductions, the stock of within-province and between-province migrants increase by roughly 15% and 82%, respectively, and aggregate labour productivity and welfare increase by 4.8% and 8.5%, respectively.

We use our model to perform a growth accounting exercise that decomposes China's aggregate labour productivity growth between 2000 and 2005 into components attributed to internal trade and migration cost reductions, external trade liberalization, and all other factors such as productivity growth within a province and sector and capital accumulation. Internal trade cost reductions account for 17% of China's aggregate real GDP per worker growth over the period, migration cost reductions account for another 10%, and the international trade liberalization account for only 7% of the growth. Our result is in stark contrast to perceptions that China's growth is an "export-led" experience. Overall, reductions in trade and migration costs account for 27% of China's aggregate labour productivity growth from 2000 to 2005, and the contributions of the reductions in internal trade and migration costs are much larger than that of the reductions in international trade costs.

We also use our model to evaluate the potential gains from further policy reforms. Despite the decline in trade and migration costs, the scope for further cost reductions beyond those measured is still large. We find moving China's internal trade costs to levels measured in Canada yields welfare gains of roughly 12%. Gains are even larger if we lower the migration costs to levels so that China's migration rates match those in the U.S., with real GDP per worker increasing by nearly 23% and welfare by 15%. Finally, we quantify the effects of allowing for private land ownership and a fully functiong land rental market so migrants no longer give up the returns to land in their home region when they move. We find the number of migrants workers would significantly increase and a welfare gain of nearly 10%.

In addition to the misallocation literature discussed earlier, we contribute to a growing literature linking international trade flows with the spatial distribution of labour and economic activity within countries, such as Cosar and Fajgelbaum (2012); Dix-Carneiro and Kovak (2014); Allen and Arkolakis (2014); Bryan and Morten (2015); Redding (2015) and Caliendo et al. (2015). There are also papers investigating internal trade or migration costs separately, such as Morten and Oliveira (2014), Bryan and Morten (2015) or Ghani et al. (2012), and empirical investigations of trade's effect on internal migration, such as McCaig and Pavcnik (2012) for Vietnam or Aguayo-Tellez and Muendler (2009) and Hering and Paillacar (2012) for Brazil. There is also a large urban-economics literature investigating the role of international trade in altering the spatial distribution of firms and factors within a country, such as Hanson (1998). Little work has been done, however, investigating the case of China – perhaps the largest and fastest expansion of trade and internal migration ever recorded. Brandt et al. (2013) use a general equilibrium model to quantify the aggregate productivity loss due to misallocation of labour and capital across space in China, but the sources of misallocation are not explicitly modeled. In contrast, we model trade and migration costs as specific sources of misallocation. Ngai et. al. (2016) investigate the impact of the *hukou* system on labour mobility in China, but their analysis is at a more aggregate level and without detailed modeling of trade and migration across space.

2 Data, Facts and Back-of-the-Envelope Calculation

In this section we briefly describe our data and leave a more detailed discussion of the data and their sources in the appendix. We then present some key facts about the Chinese economy in year 2000, focusing on regional income inequality, internal migration, and trade. We also discuss China's migration and trade policies behind these facts and the important policy changes occured between 2000 and 2005. Finally, we conduct some back-of-the envelope calculations to illustrate the potential gains from these policy changes.

2.1 Data

There are 31 provinces in mainland China. We exclude Tibet from our discussion here and the subsequent analysis due to a lack of data for the region. For each of the other 30 provinces, we divide the economy into agricultural and non-agricultural sectors. To compare real incomes across provinces and sectors, we need data on GDP, employment, and price level by province and sector. Official statistics published in the annual China Statistical Yearbook (CSY) reports nominal GDP and employment data for agriculture, industry and services in each of China's provinces, which we aggregate to agriculture and non-agriculture. The CSY also reports both the rural and urban consumer price indices for each province. In addition, for a few years in the 1990s the CSY reported retail prices of major consumer products in provincial capital cities and procurement prices of agricultural products in rural areas by province. Brandt and Holz (2006) use these data and the consumption basket weights published by China's National Bureau of Statistics (NBS) to construct rural and urban price levels in 1990 for each province. We combine these 1990 price levels and the published CPI indices to claculate the price levels in other years, and then calculate real incomes by deflating agricultural GDP and non-agricultural GDP with rural and urban price levels, repsectively.

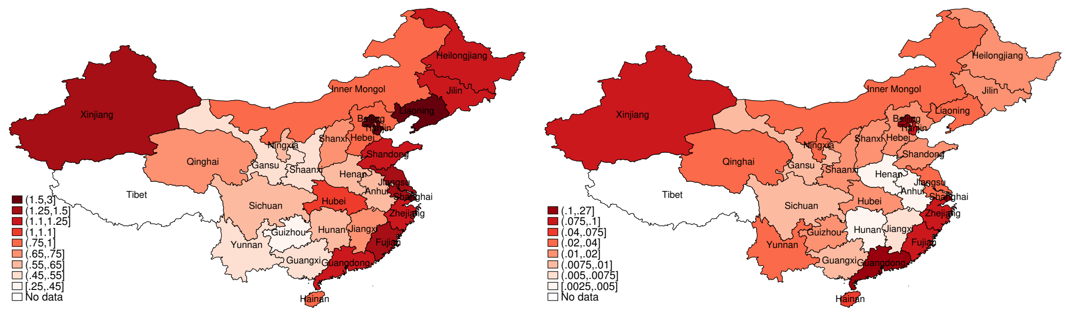
The main data sources for the labour market in China are the annual Rural Household Surveys and Urban Household Surveys conducted by the NBS. These are residence based surveys that underestiamte the number of migrant workers. For studying migration in China, researchers have generally used the Population Census as the main data source.[1] In this paper, we use the 1% sample of the 2000 Census

[1]There is a new Longitudinal Survey on Rural Urban Migration in China (RUMiC) that is designed to provide a more accurate picture of migration in China. This surve covers only nine provinces and fifteen cities in China and the survey results are largely consistent with the data from population census. See Meng (2012), who provides an overview of the labour market data in China and (Chan, 2013), who discusses migration data in China.

Figure 1: Spatial Distribution of Real Incomes and Migration in 2000

(a) Real GDP/Worker, Relative to Mean

(b) Migrant Share of Total Employment



Note: Displays choropleths of relative real income levels for each of China's provinces and the migrant share of total employment. Dark reds indicate both high relative real incomes and large migrant shares of employment.

and the 20% sample of the 2005 1% Mini Census as our data source for migration.

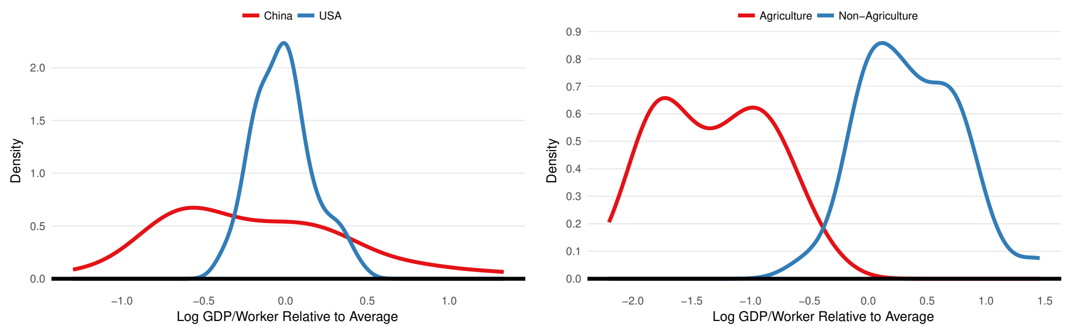
For trade data, we use the interregional input-output tables for 2002 and 2007 costructed by Li (2010) and Zhang and Qi (2012). These tables are constructed based on the data from the NBS's Provincial Input-Output Tables, Surveys of the Sources of Material Inputs for Industrial Enterprises, and the Surveys of Initial Destinations of Industrial Output, and the information on goods transportation by railways in China. (See Zhang and Qi (2012) for the details about the construction method and the original data sources.) Li (2010) reports bilateral trade flows for all provinces and for a variety of sectors in 2002. For changes in trade flows, Zhang and Qi (2012) provide the bilateral trade flows between eight aggregate regions in both 2002 and 2007.

2.2 Spatial Distribution of Income

In Figure 1a we plot the real GDP per worker for the 30 provinces in China in 2000. The figure reveals large regional income inequality in China. The ratio of the average real GDP per worker of the top five provinces to that of the bottom five provinces, for example, was 4:1. In general, the coastal provinces in the eastern region had substantially higher levels of real GDP per worker than provinces in the central and western regions.

Figure 2: Spatial Distribution of GDP per Worker (2000)

(a) Across Regions within China and the USA (b) Across China's Regions within Ag and Nonag



Note: Displays distribution of nominal GDP per worker across regions. Panel (a) compares aggregate values across China's provinces relative to the distribution across US states. Panel (b) displays values across regions of China within agriculture and non-agricultural sectors. Data for the US are from the BEA's state-level GDP and employment data. All data are for the year 2000.

As a comparison, we plot in Figure 2a the cross-state distribution of GDP per worker in the US in 2000 along with the cross-province distribution of GDP per worker in China. Since we do not have price level information for the US, we use nominal GDP per worker for both countries in the plot. It is clear that the dispersion of income is substantially larger in China than in the US. We also plot in 2b the cross-province distribution of GDP per worker within China's agricultural and non-agricultural sectors. The large dispersion of income within sectors and higher incomes in the non-agricultural sector are evident. Even after controling for price differences between rural and urban areas, the real GDP per worker in the non-agricultural sector was still much higher than that in the agricultural sector in all the provinces; the average ratio of the real GDP per worker in the two sectors within a province was 4:1. An important reason for the large real income differences across provinces and sectors in China is a *hukou* system that imposes severe restrictions on worker movements within China.

2.3 Migration Policies and Migration Patterns

In 1958, the Chinese government formally instituted a household registration system to control population mobility. Chan (2010) provides a detailed discussion of the system; we summarize its key features here. Each Chinese citizen is assigned a *hukou* (registration status), classified as "agricultural (rural)" or "nonagricultural (urban)" in a specific administrative unit that is at or lower than the county/city level. Individuals need approvals from local governments to change the category (agricultural or non-agricultural) or location of *hukou*, and it is extremely difficult to obtain such approvals. Before the economic reform started in 1978, working outside one's *hukou* location/category was prohibited. This prohibition was relaxed in the 1980s, but prior to 2003 workers without local *hukou* still had to apply for a temporary residence permit. This was difficult, so many migrant workers were without a permit and faced the consequence of being arrested and deported by the local authorities.

As the demand for migrant workers in manufacturing, construction, and labour intensive service industries increased, many provinces, especially the coastal provinces, eliminated the requirement of temporary residence permit for migrant workers after 2003. There was also a nationa-wide administrative reform in 2003 that greatly streamlined the process for getting a temporary residence permit in other provinces. These policy changes made it much easier for a worker to leave his/her *hukou* location and work somewhere else as a migrant worker. However, even with a temporary residence permit, migrant workers without local *hukou* have very limited access to local public services and face much higher costs for health care and for their children's education. So despite the reforms, the costs of being a migrant worker remain high, especially for out-of-province migrants and older workers to whom having access to public services is more important. Not surprisingly, there are more within-province than cross-province migrants, most migrant workers are young and without children, and the average duration of their stay outside the *hukou* location is only seven years (Meng, 2012).

Table 1 presents the total number of inter-provincial and intra-provincial migrant workers for 2000 and 2005 and their shares of total employment. Any worker in a province other than the province of his/her *hukou* is classified as an inter-

Table 1: Stock of Migrant Workers in China

	Inter-Provincial		Intra-Provincial	
	2000	2005	2000	2005
Total Migrant Stock (millions)	26.5	49.0	90.1	120.4
Share of Total Employment				
Total Migrants	4.2%	7.2%	14.3%	17.7%
Ag-to-Nonag Migrants	3.4%	5.6%	13.1%	16.4%

Notes: Migrants are defined based on their their *Hukou* registration location. Inter-provincial migrants are workers registered in another province from where they are employed. Intra-provincial migrants are workers registered in the same province where they are employed, but are either non-agricultural workers holding agricultural *Hukou* or vice-versa.

provincial migrant. A worker within his/her *hukou* province but in an occupation other than his/her *hukou* category (agricultural or non-agricultural) is classified as an intra-provincial migrant. Most of the intra-provincial migrant workers are rural-to-urban migrants who have agricultural *hukou* but work outside agriculture. Partly due to the migration policy changes, the numbers of inter- and intra-provincial migrant workers have both increased significantly between 2000 and 2005. By 2005, there were 49 million workers who moved across provincial boundaries and 120 million workers who switched sectors within a province. While migration of this magnitude is unprecedented, as a share of total employment it is less impressive. Despite large income disparity across provinces, inter-provincial migrant workers accounted for only 4.2% of total employment in 2000 and 7.2% in 2005. There is heterogeneity across provinces, of course. Figure 1b plots for each province the migrant workers' share of total employment in 2000. Richer provinces in coastal regions tend to have higher migrant worker shares than poorer interior provinces, and provinces with more inter-provincial migrant workers also tend to have higher intra-provincial migrant workers. We provide more details about migration patterns in the appendix.

2.4 Trade Policies and Trade Patterns

It is well known that the years between 2000 and 2005 were a period of external trade liberalizations for China as it joined the WTO at the end of 2001. It is less well known, however, that China also experienced significant internal trade liberalizations during the same period. Several researchers have documented high internal trade costs in China in the 1990s (Young, 2000; Poncet, 2005). Others have also documented that the degree of local market protection in a province was directly related to the size of the state sector in that province (Bai et al., 2004). Since 2000, these trade barriers have been reduced significantly. Some of the reduction was due to the government's deliberate policy reforms. For example, the state council under then premier Zhu Rongji issued a directive at the end of 2001 that prohibits local government from engaging in local market protections. More important, as a result of various SOE reforms, the size of the state sector has declined, and consequently the local governments have less incentives than before to engage in local market protections. Equally important, improved transport infrastructure and logistics also helped lower internal trade costs.

Table 2 reports the aggregate bilateral trade flows between the eight regions in China and between each region and the rest of the world (see the Appendix for a list of provinces by region). To ease comparisons, we normalize all flows by the importing region's total expenditures, resulting in a table of expenditure shares $\pi_{ni} = x_{ni}/\sum_{i=1}^{N} x_{ni}$, where x_{ni} is the spending by region n on goods from region i. In addition to bilateral trade flows, we report a region's share of expenditures on goods from all other regions within China in the last column, and each region's "home-share"–the fraction of its expenditures allocated to its own producers, on the diagonal of Table 2.

While the regions in China generally import more from abroad than from any particular region within China, the total imports from the rest of China are still higher than imports from abroad for most of the regions. The Central Coast and South Coast regions are the exceptions. In 2002, their imports from abroad were significantly higher than imports from the rest of China; they also had substantial international exports. Interior regions of China have much higher home-shares than coastal regions. In 2002, the central region's home share is 0.88 compared to only

Table 2: Internal and External Trade Shares of China

	Exporter									Total
Importer	North-east	Beijing Tianjin	North Coast	Central Coast	South Coast	Central Region	North-west	South-west	Abroad	Other Prov.
Year 2002										
Northeast	87.9	0.7	1.0	0.8	1.3	1.1	0.8	0.9	5.5	6.6
Beijing/Tianjin	3.9	63.4	9.4	3.0	2.6	3.3	1.4	1.2	11.9	24.8
North Coast	1.8	3.3	79.8	3.4	1.8	3.8	0.9	0.8	4.4	15.8
Central Coast	0.2	0.2	0.6	81.0	1.5	2.4	0.5	0.5	13.3	5.7
South Coast	0.5	0.4	0.5	2.6	72.3	1.9	0.4	1.5	19.8	7.9
Central Region	0.6	0.3	1.1	4.8	2.3	87.8	0.7	0.7	1.8	10.4
Northwest	2.0	0.8	2.1	3.3	4.5	3.6	77.4	3.8	2.6	20.0
Southwest	0.9	0.3	0.4	1.8	4.3	1.4	0.9	88.0	2.0	10.0
Abroad	0.0	0.0	0.0	0.1	0.2	0.0	0.0	0.0	99.6	–
Year 2007										
Northeast	78.7	2.0	2.0	0.9	2.7	1.0	1.4	0.9	10.4	10.9
Beijing/Tianjin	3.8	62.3	10.1	1.5	2.4	1.8	2.1	0.7	15.5	22.2
North Coast	2.1	5.8	76.8	1.5	1.5	3.7	2.3	0.8	5.5	17.7
Central Coast	1.1	0.7	1.4	76.8	1.8	4.8	1.7	0.9	10.8	12.4
South Coast	1.5	0.9	1.7	5.2	68.5	3.6	1.8	2.8	14.1	17.4
Central Region	1.7	1.4	4.5	4.9	4.0	73.0	2.9	1.8	5.9	21.1
Northwest	2.3	2.2	4.8	2.7	5.5	3.6	65.6	3.6	9.8	24.6
Southwest	1.6	1.2	1.7	1.7	8.4	1.9	3.2	73.8	6.6	19.6
Abroad	0.0	0.1	0.1	0.4	0.2	0.0	0.0	0.0	99.1	–

Note: Displays the share of each importing region's total spending allocated to each source region. See Appendix A (Trade Shares) for the mapping of provinces to regions. The column "Total Other Prov." reports the total spending share each importing region allocated to producers in other provinces of China. The diagonal elements (the "home share" of spending), the share imported from abroad, and the share imported from other provinces will together sum to 100%.

0.72 for the south coast and 0.63 for Beijing and Tianjin.

Due to the internal and external trade liberalizations, all regions in China became more open between 2002 and 2007, as evidenced by the decline in their home shares. For most regions, this was due to increases in import shares both from the rest of China and abroad. But, again, the Central Coast and South Coast regions are the exceptions. Their shares of imports from abroad actually declined during this period; all the declines in the two regions' home shares were due to the increases in their imports from the rest of China. Overall, imports from the rest of China increased much more than imports from abroad during this period. On average, a region's share of spending allocated to imports from the rest of China increased by nearly 7 percentage points while the share imported from abroad increased by only

1 percentage point.[2]

2.5 Potential Gains from Trade and Migration

So far we have documented that there were large dispersion of income across provinces and sectors in China in 2000, partly due to the high migration and trade costs. We also described the policy changes that helped reducing these costs between 2000 and 2005 and the increases in trade and migration during the period. What have these changes meant for China's aggregate economy? Before turning to a full general equilibrium model for answering this question, we first illustrate the potential gains from the increases in trade and migration with a back-of-the-envelope calculation based on a simple model. The calculation will show that the contributions of migration flows and increases in internal trade to the aggregate GDP growth during the period are much larger than the contribution from the increases in international trade. We will latter show that this key quantitative result still holds when the full model is used for the analysis.

Let y_n^j and l_n^j be the real GDP per worker and employment share, respectively, in region n and sector j. Then aggregate GDP per worker is $y = \sum_{n,j} y_n^j l_n^j$. Following some shock that affects sectoral or regional GDP and employment, the relative change in aggregate GDP per worker is

$$\hat{y} = \sum_{n,j} \omega_n^j \hat{y}_n^j \hat{l}_n^j = 1 + \sum_{n,j} \omega_n^j g_{y_n^j} + \sum_{n,j} \omega_n^j g_{l_n^j} + \sum_{n,j} \omega_n^j g_{y_n^j} g_{l_n^j}$$

where $\hat{x} = x'/x$ denotes relative changes in variable x, g_x its growth rate, and $\omega_n^j \propto y_n^j l_n^j$ region n and sector j's share of initial aggregate GDP.

To decompose the change in a given sector and region's real GDP, suppose that each region is an economy in the standard Eaton-Kortum model. Let π_{nn}^j, π_{nc}^j and π_{nw}^j be the expenditure shares of goods from home province, rest of China and

[2] All trade values we reported in this section are at the regional level. For 2002, we also compute trade shares for each individual province and for each sector (agriculture and nonagriculture). Consistent with the regional data, interior provinces have higher home-shares than coastal provinces, most provinces trade more with the rest of China than from abroad, but the coastal provinces trade more internationally.

abroad. Arkolakis et al. (2012) show that within a broad class of models, aggregate gains from trade can be captured by changes in home shares π^j_{nn} combined with an elasticity of trade parameter θ:

$$\hat{y}^j_n = \left(\hat{\pi}^j_{nn}\right)^{-1/\theta} \approx 1 - \frac{1}{\theta}\frac{\triangle\pi^j_{nn}}{\pi^j_{nn}}.$$

Thus, if we know the change home shares π^j_{nn} we can quantify the growth of GDP per worker. Since all shares must sum to one, we have $\triangle\pi^j_{nn} = -\triangle\pi^j_{nc} - \triangle\pi^j_{nw}$ and $g_{y^j_n} \approx \frac{1}{\theta}\left(\frac{\triangle\pi^j_{nc}}{\pi^j_{nn}} + \frac{\triangle\pi^j_{nw}}{\pi^j_{nn}}\right)$, which imply

$$\hat{y} \approx 1 + \underbrace{\sum_{n,j}\omega^j_n \frac{1}{\theta}\frac{\triangle\pi^j_{nc}}{\pi^j_{nn}}}_{\substack{\text{Internal Trade} \\ 3.6\%}} + \underbrace{\sum_{n,j}\omega^j_n \frac{1}{\theta}\frac{\triangle\pi^j_{nw}}{\pi^j_{nn}}}_{\substack{\text{External Trade} \\ 0.3\%}} + \underbrace{\sum_{n,j}\omega^j_n g_{l^j_n}}_{\substack{\text{Migration} \\ 10.8\%}}$$

To simplify matters, we ignore the quantitatively small interaction term $g_{y^j_n} g_{l^j_n}$ in this approximation.

This simple expression decomposes aggregate growth into contributions from rising internal trade, international trade, and migration. We find migration contributes nearly 11% to China's aggregate growth between 2000 and 2005, holding all other factors fixed. Increases in internal trade add 3.6% and international trade 0.3%. Migration matters because workers moved to higher productivity regions and, more important, sectors. The large productivity gap between agriculture and non-agriculture and the reallocation of labour from agriculture to non-agriculture accounts for about 90% of the gains from migration. As for the gains from trade, internal trade contributes much more to growth than the external trade, because the increase in the share of internal trade for a province is on average much larger than the increase in the share of external trade, as we documented in Section 2.

While the decomposition is illustrative about the potential gains from trade and migration, it ignores several important issues that may have significant impact on the quantitative evaluation of growth contributions. First, it does not taking into account the equlibrium relationnship between trade and migration: trade may induce migration and migration may lead to increase in trade. Second, without a structural model we cannot quantify how much of the increases in trade and migration were due to the reduction in migration and trade costs. Third, we have treated agriculture and non-agriculture symmetrically, and ignored the input-output linkages. Fourth, we may have overestiamted the gains from migration by assuming labour productivity in a province-sector is independent of migration and ignoring the dispersion factors such as land endowment and heterogeneous location preferences of workers and selection. We turn next to a genearl equilibrium model that explicitly deals with all these issues, and use it to quantify the changes in the underlying migration and trade costs and their contributions to growth.

3 Quantitative Model

Our general equilibrium model of trade and migration builds on the works by Eaton and Kortum (2002), Ahlfeldt et al. (2012) and Redding (2015). The model features two tradable sectors and multiple regions of China between which goods and labour may flow. Our main departure from these papers is that we introduce between-region migration frictions and within-region rural-to-urban migrations.

There are $N+1$ regions representing China's provinces plus the rest of the world. Each region has two sectors: agriculture and nonagriculture, denoted $j \in \{ag, na\}$. Each region is also endowed with a fixed factor (land, structures), denoted $\overline{S}_n^j$, that is used for housing and production. Finally, there are $\bar{L}_n^j$ workers *registered* in region n and sector j. Workers can migrate between sectors within a region and between provinces within China, but there is no labour mobility between China and the rest of the world. Denote the total number of workers employed in region n and sector j as L_n^j and the number of migrant workers from region n' and sector j' as $L_{n'n}^{j'j}$.

3.1 Worker Preferences

Workers derive utility from final goods and residential housing. The representative worker in sector j maximizes the Cobb-Douglas utility

$$u_n^j = \left[\sum_{k \in \{ag,na\}} \left(C_n^{j,k} \right)^{\alpha \varepsilon^k} \right] \left(S_n^{j,h} \right)^{1-\alpha}, \tag{1}$$

where $C_n^{j,k}$, $j = ag, na$, are consumption of agricultural and nonagricultural goods, respectively, and $S_n^{j,h}$ is housing structures.[3] The parameters α and ε are preference weights. Overall, total consumption of k good in region n sector j is $C_n^{j,k} L_n^j$. Households are subject to a budget constraint $P_n^{j,ag} C_n^{j,ag} + P_n^{j,na} C_n^{j,na} + r_n^j S_n^{j,h} \leq v_{n'n}^{j'j}$, where $P_n^{j,ag}$ and $P_n^{j,na}$are consumption good prices, r_n^j the price of housing, and $v_{n'n}^{j'j}$ nominal income of a worker with *hukou* in region n' and sector j'. Let $v_n^j = \sum_{j',n'} v_{n'n}^{j'j} L_{n'n}^{j'j} / L_n^j$ be the average income of workers in region n and sector j. Then, it is straightforward to show that final demand for good k in region n is

$$D_n^k = \alpha \varepsilon^k \sum_{j,} v_n^j L_n^j. \tag{2}$$

Similarly, final demand for housing is $(1-\alpha) \sum_j v_n^j L_n^j$.

3.2 Production, Trade and Goods Prices

Agricultural and nonagricultural goods are composites of a continuum of horizontally differentiated varieties $y_n^j(\nu)$, $j = ag, na$; $\nu \in [0,1]$. A perfectly competitive firm produces good j using the CES technology

$$Y_n^j = \left(\int_0^1 y_n^j(\nu)^{(\sigma-1)/\sigma} d\nu \right)^{\sigma/(\sigma-1)},$$

[3]The homothetic preferences greatly simplifies the analysis. In the Appendix, we expand the model to allow subsistence food requirements. All our key results go through with only minor quantitative differences.

where σ is the elasticity of substitution across varieties. Each variety ν may be sourced from local producers or imported, whichever minimizes costs. The good Y_n^j is either consumed directly by households or used as intermediate inputs by producers of differentiated varieites. These varieties are produced by perfectly competitive firms using labour, intermediate inputs, and land with Cobb-Douglas technologies. The marginal cost of production for a firm with productivity φ is therefore

$$c_n^j(\varphi) \propto \frac{1}{\varphi}\left[w_i^{j\,\beta^j} r_i^{j\,\eta^j}\left(\prod_{k\in\{ag,na\}} P_i^{k\,\sigma^{jk}}\right)\right], \tag{3}$$

where β^j and η^j are labour and land shares, and σ^{jk} share for intermediate input from sector k such that $\beta^j+\eta^j+\sum^k\sigma^{jk}=1$. Also, w_n^j is the wage, r_n^j the rental cost of land, and P_n^k the price of intermediate input from sector k, which is the same as the price of the final good Y_n^k. For notation convenience, we follow Caliendo and Parro (2012) and define c_n^j the term in the brackets in equation 3.

Producers in one region can sell to consumers in another region by incurring an iceberg cost: they need to ship τ_{ni}^j units from region i for one unit to arrive in region n. We assume agricultural and nonagricultural households within the same province n face the same prices. So consumer prices are $p_{ni}^j(\varphi)=\tau_{ni}^j c_n^j(\varphi)$ for both types of households.

Trade depends on where, for any given buyer, the cheapest source for each variety ν is located. Denote π_{ni}^j the fraction of region n spending allocated to sector j goods produced in region i (trade shares). As in Eaton and Kortum (2002), if φ is distributed Frechet with CDF $F_i^j(\varphi)=e^{-T_i^j\varphi^{-\theta}}$ then equilibrium trade shares are

$$\pi_{ni}^j=\frac{T_i^j\left(\tau_{ni}^j c_i^j\right)^{-\theta}}{\sum_{m=1}^{N+1}T_m^j\left(\tau_{nm}^j c_i^j\right)^{-\theta}}, \tag{4}$$

and final good prices are

$$P_n^j=\gamma\left[\sum_{m=1}^{N+1}T_m^j\left(\tau_{nm}^j c_m^j\right)^{-\theta}\right]^{-1/\theta}, \tag{5}$$

where γ is a constant,[4] and T_i^j is a productivity parameter that determines the average labour productivity of firms in region i and sector j under autarky, which could be influenced in the data by the average production efficiency and average capital intensity of firms, and capital allocation across firms within the region and sector. Brandt et al. (2013) show that average capital intensity does not vary much across the Chinese provinces, so spatial misallocation of capital is not a quantitatively important issue and we abstract it from our analysis in this paper.

Let X_n^j be total expenditures on good j by region n. Total revenue is then

$$R_n^j = \sum_{i=1}^{N+1} \pi_{in}^j X_i^j. \tag{6}$$

Combined with demand for intermediates by producers, we have

$$X_n^j = D_n^j + \sum_k \sigma^{kj} R_n^k. \tag{7}$$

3.3 Incomes of Workers

Housing structures and land for production are not tradable and are owned in common by local residents. This assumption is broadly consistent with the institutional features of China, and implies that migrant workers have no claim to local fixed factor income.

As consumer preferences and production technologies are Cobb-Douglas, total spending on the fixed factor is $(1-\alpha)v_n^j L_n^j + \eta^j R_n^j = (1-\alpha)v_n^j L_n^j + \eta^j \beta^{j-1} w_n^j L_n^j$. Given a total fixed-factor endowment of $\overline{S}_n^j$, the market clearing condition for the fixed-factor is $r_n^j \overline{S}_n^j = (1-\alpha)v_n^j L_n^j + \eta^j \beta^{j-1} w_n^j L_n^j$. Add fixed-factor income to labour income we have $v_n^j L_n^j = (1-\alpha)v_n^j L_n^j + \eta^j \beta^{j-1} w_n^j L_n^j + w_n^j L_n^j$. Solving for $v_n^j L_n^j$ yields the following equation:

$$v_n^j L_n^j = \frac{\eta^j + \beta^j}{\alpha \beta^j} w_n^j L_n^j.$$

[4] We assume that the dispersion parameter θ is common to all regions and sectors. As in Caliendo et al. (2013) and Albrecht and Tombe (2016), this parameter is the same within as between countries. In the calibration to come, we argue that the existing within-country estimate of θ is close to the between-country estimates.

And the total fixed-factor income in region n sector j is

$$r_n^j \overline{S}_n^j = \left[\frac{(1-\alpha)\beta^j + \eta^j}{\alpha \beta^j} \right] w_n^j L_n^j. \tag{8}$$

As only workers with local *hukou* receive fixed-factor income, the income of a local worker in region n and sector j is $v_{nn}^{jj} = w_n^j + r_n^j \overline{S}_n^j / L_{nn}^{jj}$ and the income of a migrant worker is simply w_n^j. If we define

$$\delta_{in}^{kj} = \begin{cases} 1 + \frac{(1-\alpha)\beta^j + \eta^j}{\alpha \beta^j L_{nn}^{jj}} & if\ n = i\ and\ j = k \\ 1 & if\ n \neq i\ or\ j \neq k \end{cases}, \tag{9}$$

as the effective fixed-factor "rebate rate" to workers, then we can write the incomes of workers in region n and sector j as $v_{in}^{kj} = \delta_{in}^{kj} w_n^j$. Note that our assumption about the distribution of fixed-factor income is different from the standard assumption of equal rebate (either proportional to wage as in Redding (2015) or lump-sum as in Caliendo et al. (2013)) to workers within each region and sector, regardless of their migrant status. Our assumption is motivated by the actual land ownership institution in China, which has an important negative effect on migration.

3.4 Internal Migration

Workers can move across provinces and sectors within China, but not internationally. Each worker is registered to a province and assigned either an agricultural or a nonagricultural *hukou*. Let m_{ni}^{jk} denote the share of workers registered in region n and sector j who migrated to region i to work in sector k. There are costs to migration. First, migrants must forego the returns to land in their home region, and rely only on labour income wherever they move. In addition, workers incur a utility cost that lowers welfare by a factor $\mu_{ni}^{jk} > 1$. Finally, workers differ in their tastes over locations, which is formally represented by a vector of multiplicative preference factor ε_i^k for each of the $N \times 2$ region-sectors. We assume that ε_i^k is i.i.d. across workers, regions, and sectors.

Given real wages $V_i^k \equiv w_i^k / \left(P_i^{ag\ \varepsilon} P_i^{na\ 1-\varepsilon} \right)^{\alpha} r_i^{k\ 1-\alpha}$ in all regions and sectors, workers from (n,j) maximize their welfare $\varepsilon_i^k \delta_{ni}^{jk} V_i^k / \mu_{ni}^{jk}$. As ε_i^k is a random variable across a continuum of individuals from (n,j), the law of large numbers ensures that the proportion of these workers who migrate to region (i,k) is

$$m_{ni}^{jk} = Pr\left(z_i^k \delta_{ni}^{jk} V_i^k / \mu_{ni}^{jk} \geq \max_{i',k'} \left\{ z_{i'}^{k'} \delta_{ni'}^{jk'} V_{i'}^{k'} / \mu_{ni'}^{jk'} \right\} \right).$$

This proportion can be solved explicitly if preferences over locations follow a Frechet distribution with CDF $F_z(x) = e^{-x^{-\kappa}}$, where κ governs the degree of dispersion across individuals. A large κ implies small dispersion.

Proposition 1 *Let $\mu_{nn}^{ii} = \left(\delta_{nn}^{ii}\right)^{-1}$. Given real wages for each region and sector V_i^k, migration costs between all region-sector pairs μ_{ni}^{jk}, and heterogeneous preferences distributed $F_z(x)$, the share of (n,j)-workers that migrate to (i,k) is*

$$m_{ni}^{jk} = \frac{\left(V_i^k / \mu_{ni}^{jk}\right)^{\kappa}}{\sum_{k'} \sum_{i'=1}^{N} \left(V_{i'}^{k'} \delta_{ni'}^{jk'} / \mu_{ni'}^{jk'}\right)^{\kappa}}, \tag{10}$$

and total employment at (i,k) is $L_i^k = \sum_j \sum_{n=1}^{N} m_{ni}^{jk} \bar{L}_n^j$.

Proof: See the appendix.

While our assumptions about migration costs are particular, they do not drive the results. We could have alternatively modelled migration costs as affecting worker productivity, or allowed for heterogeneous productivity. We explore these possibilities in the appendix, including cases where productivity is correlated or uncorrelated across regions and sectors. Our main quantitative results are robust to these different modeling assumptions about migration.

3.5 Solving and Calibrating the Model

To ease our quantitative analysis and calibration, we follow Dekle, Eaton, and Kortum (2007) and solve for counterfactual *changes*. Let $\hat{x} = x'/x$ be the equilibrium relative change in variable x in response to some exogenous change in model parameters. As this approach is increasingly familiar in quantitative trade research, we provide the relevant expressions in the appendix. Here, we present only the relevant changes in aggregate welfare and real GDP.

Proposition 2 *Given changes in migration and real incomes, the change in aggregate welfare is*

$$\hat{W} = \sum_j \sum_{n=1}^{N} \omega_n^j \hat{V}_n^j \hat{m}_{nn}^{j\;-1/\kappa}, \tag{11}$$

where $\omega_n^j \propto \bar{L}_n^j V_n^j m_{nn}^{j\;-1/\kappa}$ *is region n and sector j's initial contribution to welfare.*

Similarly, the change in real GDP is

$$\hat{Y} = \sum_j \sum_{n=1}^{N} \phi_n^j \hat{V}_n^j \hat{L}_n^j, \tag{12}$$

where $\phi_n^j \propto V_n^j L_n^j$ *is the contribution of region n and sector j to initial real GDP.*

Proof: See the appendix.

Solving the model in relative changes eases the model calibration by eliminating many fixed components of the model. Specifically, the model requires we calibrate parameters $(\alpha, \beta^j, \eta^j, \sigma^{jk}, \theta, \kappa)$ and initial values $(\pi_{ni}^j, m_{ni}^{jk}, \bar{L}_i^j, V_i^j)$, nothing more. Below, we describe how we calibrate these components of the model and provide a summary in Table 3.

3.5.1 Observable Parameters

The production function parameters are the labour and land shares of gross output β and η, along with intermediate input shares σ. We postpone a detailed discussion of this data to the appendix. For α, we use consumer expenditure data from the most recent China Statistical Yearbook. The fraction of urban household spending on housing is 11% and for rural households is 15%. We set $\alpha = 0.87$, implying the housing share of expenditures is 13%.

The total registrants by province and sector $(\bar{L}_n^j)$ are directly observable in China's 2000 Population Census (see the appendix). Total national employment for China is 636.508 million. Total employment in the rest of the world $(\sum_j L_{N+1}^j)$ is 2,103 million. This is inferred from the Penn World Table as the total non-China

Table 3: Calibrated Model Parameters and Initial Values

Parameter	Set To	Description
(β^{ag}, β^{na})	$(0.40, 0.24)$	Labour's share of output
(η^{ag}, η^{na})	$(0.13, 0.02)$	Land's share of output
$(\sigma^{ag,na}, \sigma^{na,ag})$	$(0.60, 0.06)$	Intermediate input shares
α	0.87	Goods' expenditure share
θ	4	Elasticity of trade
κ	1.5	Elasticity of migration
π_{ni}^{j}	*Data*	Bilateral trade shares
m_{ni}^{j}	*Data*	Bilateral migration shares
$\bar{L}_{n}^{j}$	*Data*	Hukou registrations

Notes: Displays model parameters, their targets, and a description. See text for details.

employment for 2000. China's initial migration shares m_{ni}^{jk} are calculated directly from the 2000 Population Census. Since we don't have trade data in 2000, we use the trade shares generated from the 2002 China Regional Intput-Output Tables to approximate the values of the trade shares π_{ni}^{j} in 2000. Finally, to get initial real income per worker V_n, we use data on real GDP per worker by province and sector. In the model, the two are equivalent as trade balances.

3.5.2 Cost-Elasticity of Trade

There is a large literature on the productivity dispersion parameter θ. This parameter governs productivity dispersion across firms and, consequently, determines the sensitivity of trade flows to trade costs. Between-countries, there are many estimates of this elasticity to draw upon. For example, Simonovska and Waugh (2011) use cross-country price data to estimate $\theta \approx 4$. Parro (2013) estimates $\theta \in [4.5, 5.2]$ for manufacturing using trade and tariff data. Based on this method, Tombe (2015) estimates $\theta = 4.1$ for agriculture and 4.6 for nonagriculture. Within-countries, however, there is little evidence to draw upon. Using firm-level productivity dispersion in the US, Bernard et al. (2003) estimates $\theta = 3.6$. We set $\theta = 4$ and explore alternative values in the appendix.

3.5.3 Income-Elasticity of Migration

In our model, we can write the normalized inter-provincial migration flows from (n, j) to (i,k) as a function of real wage differences and migration costs,

$$ln\left(\frac{m_{ni}^{jk}}{m_{nn}^{jj}}\right) = \kappa ln\left(\frac{V_i^k}{V_n^j}\right) - \kappa ln\left(\mu_{ni}^{jk}\right),$$

and the parameter κ governs the income-elasticity of migration. If income differences were exogenous, one could estimate κ with a simple OLS regression. But income differences are themselves influenced by migration flows and factors that are potentially related to migration costs – such as remoteness or the institutional quality of the receiving region. To deal with the endogeneity issue, we consider two instruments: (1) output exported internationally in 1997 and (2) the average income of neighbouring provinces. The justifications for the instruments are as follows. Previous export-oriented provinces will tend to have high incomes, but migration in 2000 will not itself affect past export behaviour. Also, a region whose neighbours have high-income will tend to have high income, but the neighbour's income is plausibly exogenous to a given region's migration or income shocks. Of course, neither of these instruments address concerns over unobserved institutional factors that affect a region's attractiveness to migrants, income, and export share silmutaneously – especially if such unobserved factors are spatially correlated. Using region or region-pair fixed effects in our regression mitigates such concerns. We provide the resulting estimates for κ in Table 4

Though our estimates vary slightly, we opt to set $\kappa = 1.5$.[5] In the appendix we show our main quantitative results are robust to a variety of values for κ. For context, there are recent estimates in similar models applied to the United States. Fajgelbaum et al. (2015) use variation in state-level taxes to estimate the elasticity of migration. They specifically use a distance-weighted average of tax rates in all other states to instrument for each state's own taxes. While their estimates vary across a number of model specifications, the closest to our setup corresponds to $\kappa = 1.39$. In

[5] We also use migration shares in 2005 and find similar estimates, though a wider range of $\kappa \in [1.09, 2.22]$.

Table 4: Estimates of the Income-Elasticity of Migration in China

	OLS		IV			
			1997 Export Shares		Neighbouring Income	
	(1)	(2)	(3)	(4)	(5)	(6)
Income Gap	1.47***	1.39***	1.98***	1.59***	1.45***	1.45***
	[0.05]	[0.05]	[0.08]	[0.05]	[0.06]	[0.05]
Distance	-1.18***		-1.18***		-1.18***	
	[0.05]		[0.05]		[0.05]	
Constant	-0.84**	-9.86**	-0.84**	-9.80***	-0.84**	-9.84***
	[0.33]	[0.64]	[0.33]	[0.55]	[0.33]	[0.55]
(n,i)-FEs	No	Yes	No	Yes	No	Yes
Obs.	3248	3248	3248	3248	3248	3248
First-Stage: Dep. Var. is Income Gap						
1997 Export Shares			0.22***	0.38***		
			[0.004]	[0.005]		
Neighbouring Income					0.44***	0.44***
					[0.005]	[0.002]
F-Stat			1605	11.4	4650	61

Note: Displays the results of various regressions of the form $ln(m_{ni}/m_{nn}) = \kappa ln(V_i/V_n) - \kappa ln(\mu_{ni})$. The first IV uses 1997 exports as a fraction of each province's total output to instrument for income in 2000. The second IV uses the distance-weighted average income of all other provinces.

addition, in the appendix we explore an alternative model where workers differ in productivity rather than preferences. In that setting, κ maps directly into observable moments of the individual earnings distribution and there is no need to estimate the income-elasticity of migration. With the individual earnings data reported in China's 2005 population census, we find κ ranges from 1.5 to 2.5, depending on the specification.

4 Inferring Trade and Migration Costs

In this section, we quantify the migration costs within China and trade costs between China's provinces and the world.

4.1 Migration Costs

Equation 10 provides a simple representation of migration decisions through which we infer migration costs. Specifically, given migration shares and initial real incomes, migration costs are

$$\mu_{ni}^{jk} = \frac{1}{\delta_{nn}^{jj}} \left(\frac{V_i^k}{V_n^j} \right) \left(\frac{m_{nn}^{jj}}{m_{ni}^{jk}} \right)^{1/\kappa},$$

where δ_{nn}^{jj} can be calculated directly from Equation 9. We find that μ_{ni}^{jk} averages around 3.6 in 2000, meaning a migrant's welfare is 3.6 times lower than if there were no migration costs. We summarize these costs, their changes between 2000 and 2005, and the initial migrant stocks in 2000 in Table 5. Overall, migration costs are largest for migrants switching both sectors and provinces – with an average initial cost of nearly 38. In contrast, to switch sectors within one's home province workers incur average migration costs of 2.9. For direct monetary cost of migrating – the loss of implicit fixed factor income from their home region – we find that δ_{nn}^{jj} averages around 1.5. Thus, the overall cost of migrating $\delta_{nn}^{jj}\mu_{ni}^{jk}$ averages around 5.33.

How do these costs change over time? We report the change in average migration costs in the last column of Table 5. Overall, migration costs declined to 84% of their initial level. Costs to switch provinces fell the most, from 32.6 to 19.8. Sectoral switches within a worker's home region also fell a lot, from 2.9 to 2.4. We use the full set of migration cost changes between all province-sector pairs in the quantitative analysis to come.

While the estimated migration costs are indeed large, they are not unreasonable. These magnitudes are consistent with individual survey data from the 2002 China Household Income Project. This survey asks Rural-Urban migrants both what they currently earn and what they could earn if they were still in their home village. The typical respondent earns roughly 4 times what they believe they would in their home village, suggesting substantial migration costs exist to maintain such a large gap. These are costs for workers who did migrate. There is substantial heterogeneity across workers and the costs faced by those who did not migrate could be

Table 5: Migration Rates and Average Migration Costs

	Initial Share of Employment	Migration Costs μ_{ni}^{jk} Level in 2000	Level in 2005	Relative Change
Overall	0.174	3.6	3.0	0.84
Agriculture to Nonagriculture Migration Cost Changes				
Overall	0.16	3.4	2.9	0.84
Within Prov.	0.13	2.9	2.4	0.84
Between Prov.	0.03	37.8	23.2	0.61
Between Provinces Migration Cost Changes				
Overall	0.04	32.6	19.8	0.61
Within Ag.	0.003	71.9	63.7	0.89
Within Nonag.	0.01	21.3	12.4	0.58

Notes: Displays migration-weighted harmonic means of migration costs in 2000 and 2005. The migrant share of employment summarizes m_{ni}^{jk} in 2000. We use initial (year 2000) weights to average the 2005 costs to ensure the displayed change reflects changes in costs and not migration patterns.

much higher. Census 2005 provides sufficient data so that we can estimate μ_{ni}^{jk} by age. Given a region and sector's real income per worker V_n^j, we can apportion this across workers in age-cohort c based on observed relative wages. Specifically, define $V_{n,c}^j = \left(w_{n,c}^j/\bar{w}_{n,c}^j\right) V_n^j$ where $\bar{w}_n^j$ is the employment-weighted average wage across cohorts in the data. Given $V_{n,c}^j$ and cohort-specific migration shares $m_{ni,c}^{jk}$, we estimate cohort-specific migration costs $\mu_{ni,c}^{jk}$. We find cross-province migration costs average 2.15 among those under age 24, significantly lower than the average costs across all age groups that we reported in Table 5.[6]

We should note that part of our measured migration costs may also be attributed to workers' location preferences that vary systematically across provinces. For example, if amenity values are higher in some of the low income provinces than other high income provinces, then holding migration costs constant, there would be less migration from these low income provinces to high income provinces. Since we have assumed in our model no amenity difference across provinces, the model im-

[6]We cannot incorporate age-specific costs into our analysis, as individual income data are not available in Census 2000. We therefore cannot estimate changes in those costs. We report the levels here for perspective.

plied migration costs would be upward biased. However, since all of our quantitative exercises will be about the impact of the changes in migration costs, this bias in the level of migration costs will not affect our results as long as the location preferences do not change over time.

4.2 Modified Head-Ries Index of Trade Costs

To estimate trade costs, we follow Head and Ries (2001) to back-out trade costs between region n and i for sector j goods using only observable trade shares and the trade-cost elasticity θ. Specifically,

$$\bar{\tau}_{ni}^{j} \equiv \sqrt{\tau_{ni}^{j}\tau_{in}^{j}} = \left(\frac{\pi_{nn}^{j}\pi_{ii}^{j}}{\pi_{ni}^{j}\pi_{in}^{j}}\right)^{1/2\theta}, \tag{13}$$

which is a direct result of equation 4 but generalizes to a broad class of trade models. This method has a number of advantages. In particular, $\bar{\tau}_{ni}^{j}$ is not affected by trade volumes or by third-party effects and applies equally well whether trade balances or not. Unfortunately, these trade cost estimates are symmetric in the sense that goods moving from i to n is as costly as moving goods from n to i. This matters, as Waugh (2010) demonstrates that international trade costs systematically differ depending on the direction of trade. To capture this, we presume trade cost asymmetries are exporter-specific such that $\tau_{ni}^{j} = t_{ni}^{j}t_{i}^{j}$, where t_{ni}^{j} are symmetric costs ($t_{ni}^{j} = t_{in}^{j}$) and t_{i}^{j} are costs of exporting. This and equation 13 imply an Adjusted-Head-Ries Index $\tau_{ni}^{j} = \bar{\tau}_{ni}^{j}\sqrt{t_{i}^{j}/t_{n}^{j}}$, as in Tombe (2015).

To estimate asymmetric components of trade costs within China, we closely follow the existing international trade literature and therefore leave details to the appendix. Essentially, we use a standard gravity regression to infer asymmetries from fixed effects. Overall, we find that poor regions face the highest exporter-specific trade costs – consistent with existing cross-country evidence – and find they are largely unchanged from 2002 to 2007. We report the relative changes in our trade cost estimates in Table 6; some notable patterns emerge. Internal trade costs are largely decreasing, with trade-weighted change in trade costs within China of $\bar{\hat{\tau}}_{ni}^{ag} = 0.87$ and $\bar{\hat{\tau}}_{ni}^{na} = 0.89$. For trade between China and the world, the average

Table 6: Relative Changes of Bilateral Trade Costs

Importer	Exporter: North-east	Beijing Tianjin	North Coast	Central Coast	South Coast	Central Region	North-west	South-west	Abroad
Change in Trade Costs in Agriculture, $\hat{\tau}_{ni}^{ag}$									
Northeast		1.34	0.88	1.17	1.66	1.24	1.31	0.90	0.96
Beijing/Tianjin	0.92		0.63	0.79	1.16	0.91	0.92	0.64	0.72
North Coast	0.80	0.83		0.82	1.11	0.77	0.72	0.61	0.72
Central Coast	0.78	0.77	0.60		1.41	0.83	0.65	0.77	0.76
South Coast	0.78	0.79	0.57	0.99		0.87	0.72	0.70	0.73
Central Region	1.01	1.08	0.68	1.01	1.50		0.86	0.87	0.77
Northwest	1.31	1.35	0.79	0.98	1.54	1.07		0.81	0.61
Southwest	0.85	0.89	0.64	1.10	1.41	1.02	0.76		0.73
Abroad	0.95	1.03	0.78	1.12	1.53	0.93	0.60	0.76	
Change in Trade Costs in Nonagriculture, $\hat{\tau}_{ni}^{na}$									
Northeast		0.90	0.91	0.84	0.79	0.82	0.83	0.88	0.80
Beijing/Tianjin	0.84		0.90	0.91	0.89	0.79	0.73	0.86	0.79
North Coast	0.87	0.93		1.00	0.86	0.78	0.72	0.78	0.81
Central Coast	0.76	0.88	0.95		0.85	0.82	0.75	0.86	0.82
South Coast	0.77	0.93	0.88	0.92		0.80	0.72	0.81	0.94
Central Region	0.87	0.91	0.86	0.96	0.88		0.76	0.84	0.75
Northwest	0.95	0.91	0.86	0.96	0.85	0.83		0.88	0.68
Southwest	0.89	0.94	0.83	0.97	0.84	0.80	0.78		0.74
Abroad	0.87	0.92	0.92	0.98	1.05	0.76	0.64	0.79	

Note: Displays changes in bilateral trade cost (relative to within-region costs) for agriculture and nonagriculture for eight broad regions. The eight regions are classified as: Northeast (Heilongjiang, Jilin, Liaoning), North Municipalities (Beijing, Tianjin), North Coast (Hebei, Shandong), Central Coast (Jiangsu, Shanghai, Zhejiang), South Coast (Fujian, Guangdong, Hainan), Central (Shanxi, Henan, Anhui, Hubei, Hunan, Jiangxi), Northwest (Inner Mongolia, Shaanxi, Ningxia, Gansu, Qinghai, Xinjiang), and Southwest (Sichuan, Chongqing, Yunnan, Guizhou, Guanxi, Tibet). In the simulation, we apply these changes to the provinces within each region.

change in costs were $\bar{\hat{\tau}}_{ni}^{ag} = 0.77$ and $\bar{\hat{\tau}}_{ni}^{na} = 0.92$.

Though our goal is only to quantify the effect of these decreases, rather than identify the underlying cause, some simple analysis is revealing. Consider isolating the portion of trade costs $\bar{\tau}_{ni}^{j} = t_{ni}^{j}\sqrt{t_i^j t_n^j}$ due to geographic distance between regions by regressing it on bilateral geographic distance and a set of importer and exporter fixed-effects by sector.[7] For 2002, we estimate the distance elasticity of 0.51 in agriculture and 0.38 in non-agriculture. For 2007, these fall to 0.40 and 0.36, respectively. If all other factors remain unchanged, the relative change in trade costs between region n and i would have been $\hat{\tau}_{ni}^{ag} = d_{ni}^{-0.11}$ and $\hat{\tau}_{ni}^{na} = d_{ni}^{-0.02}$. Overall, this averages across pairs to $\bar{\hat{\tau}}_{ni}^{ag} = 0.48$ and $\bar{\hat{\tau}}_{ni}^{na} = 0.90$. Though this is a rough ap-

[7]Specifically, estimate δ^j from $ln(\bar{\tau}_{ni}^{j}) = \delta^j ln(d_{ni}) + \iota_n^j + \eta_i^j + \varepsilon_{ni}^j$ where d_{ni} is the geographic distance between region n and i, and ι_n^j and η_i^j are importer and exporter fixed-effects by sector (to control for t_i^j and t_n^j).

proximation, it suggests nearly all of the change in nonagricultural trade costs are due to lower costs related to distance and therefore potentially due to improvements in transportation infrastructure and reductions in highway tolls.

5 Quantitative Analysis

In our quantitative analysis, we fit the initial equilibrium of our model to the Chinese data in 2000[8] and then quantify the impacts on aggregate productivity and welfare of the measured changes in trade and migration costs that we reported in Section 4. In particular, we examine how much of China's real GDP growth between 2000 and 2005 can be accounted for by the reductions in trade and migration costs.

5.1 The Effect of Lower Trade Costs

From the initial equilibrium in 2000, we solve the changes in equilibrium outcomes by using $\hat{\tau}_{ni}^{j}$ from section 4.2, and hold migration costs and productivity parameters fixed ($\hat{\mu}_{ni}^{j} = \hat{T}_{n}^{j} = 1$ for all n and i). Table 7 displays the change in trade and migration flows, aggregate productivity and welfare, and various other outcomes. Changes in trade shares are expenditure weighted average changes across all provinces and sectors. Lower internal trade costs, not surprisingly, lower the amount of international trade as households and firms reorient their purchase decisions towards domestic suppliers. The share of expenditures allocated to producers in another province typically increase by over 9 percentage points while the share allocated to international producers falls by less than one percentage point. Lower external trade costs reveal the opposite pattern. Home shares fall in both cases, but by a much larger amount in response to the internal trade cost reductions.

In terms of migration, reductions in internal trade costs actually result in *fewer* workers living outside their home province. The total stock of migrants declines by 2% (equivalent to approximately 0.5 million workers). Intuitively, reductions in internal trade costs disproportionately lower goods prices in poor, interior regions.

[8] There is no regional input-output table for 2000 in China, so we use trade shares from the 2002 China Regional Input-Output Tables to approximate trade shares in 2000.

Table 7: Effects of Trade Cost Changes

	Trade/GDP Ratio (p.p. Change)		Migrant Stock			
	Internal	External	Within Province	Between Province	Real GDP per worker	Aggregate Welfare
Internal Trade	9.2	-0.7	0.8%	-2.0%	10.7%	10.7%
External Trade	-0.7	3.9	1.8%	2.4%	3.8%	2.6%
All Trade	8.2	2.9	2.5%	0.3%	14.4%	13.2%
Agricultural Trade Cost Changes						
Internal	0.7	0.0	0.2%	-1.7%	1.1%	1.2%
External	-0.1	0.3	2.2%	2.2%	0.7%	-0.5%
Both Ag.	0.6	0.2	2.1%	0.4%	1.7%	0.7%
Non-Agricultural Trade Cost Changes						
Internal	8.5	-0.7	0.7%	-0.4%	9.6%	9.4%
External	-0.6	3.6	-0.2%	0.3%	3.1%	3.1%
All Nonag.	7.6	2.7	0.3%	-0.3%	12.6%	12.5%

Notes: Displays aggregate response to various trade cost changes. All use trade cost changes as measured, though set $\hat{\tau}^j_{ni} = 1$ for certain (n,i,j) depending on the experiment. The change in internal and external trade shares are the expenditure weighted average changes in region's $\sum_{n\neq i}\pi^j_{ni}$ and π^j_{nN}. The migrant stock is the number of workers living outside their province of registration.

The resulting increase in real income means that fewer workers are willing to migrat than before. On the other hand, a greater fraction of workers switched sectors within their home province. With lower international trade costs, richer coastal regions disproportionately benefit, so more workers relocate there in addition to more workers switching sectors within their home province. This migration response also matters for the gains from trade cost changes. Setting $\hat{L}^j_n = \hat{m}^{jj}_{nn} = 1$ in the welfare equation reveals the migration response accounts for roughly 10% of the gains.

The change in income, goods and land prices, and worker's location decision all have implications for aggregate welfare. We report the change in welfare and aggregate real GDP in the last columns of Table 7. In response to lower internal trade costs, internal trade to GDP ratio increases by as a percentage of GDP increase aggregate welfare dramatically increases by nearly 11%. In contrast, external trade cost reductions result in a much smaller gain of only 3.1%. These results are similar to those of the back-of-the-envelope calculation we reported in Section 3, and follow from the larger contributions internal trade cost reductions made to falling home shares π^{jj}_{nn}.

We also investigate the results of changing trade costs in agriculture and nonagriculture separately, which are reported in the lower panels of Table 7. Gains from

Table 8: Effects of Various Migration Cost Changes

	Trade/GDP Ratio (p.p. Change)		Migrant Stock			
	Internal	External	Within Province	Between Province	Real GDP per worker	Aggregate Welfare
All	0.1	0.2	14.5%	82.4%	4.8%	8.5%
Agriculture to Nonagriculture Migration Cost Changes						
Overall	0.1	0.1	15.3%	54.0%	4.4%	7.2%
Wthn Prov	0.0	-0.1	22.8%	-9.6%	2.0%	4.8%
Btwn Prov	0.1	0.2	-7.0%	71.0%	2.9%	2.7%
Between Provinces Migration Cost Changes						
Overall	0.1	0.3	-7.8%	99.6%	3.3%	4.0%
Wthn Ag	0.0	0.0	-0.1%	2.4%	0.0%	0.0%
Wthn Nonag	0.1	0.1	-1.0%	31.1%	0.7%	1.5%

Notes: Displays aggregate response to various migration cost changes. All use migration cost changes as measured, though set $\hat{\mu}_{ni}^{kj} = 1$ for certain (n,i,j,k) depending on the experiment. The migrant stock is the number of workers living outside their province of registration.

internal trade cost changes in agriculture are 1.2% while the gains from external trade cost changes are actually negative, at -0.5% (largely from losses to agriculture in Shanghai and Hainan, which clearly do not have comparative advantage in agriculture). For nonagriculture, internal trade cost reductions increase aggregate welfare by over 9% and external liberalization increases welfare by 3.1%. Overall, reductions in internal nonagricultural trade costs are the most important for aggreagte welfare.

5.2 Lower Migration Costs

While trade liberalization accounts for only limited migration, lower migration costs lead to substantially more movements of workers across provinces and sectors. We report the effects of migration cost reductions in Table 8.

The stock of migrants increases dramatically when the changes in migration costs, $\hat{\mu}_{ni}^{jk}$, are as measured. The number of inter-provincial migrants increases by about 82% – from little more than 4% to 7.5% of the labour force. This is equivalent to an increas of over 21 million migrant workers. Within provinces, there are also substantial moves from agriculture to nonagriculture. The stock of workers with agricultural *hukou* that have nonagricultural employment within their home province increases by nearly 15%, from over 13% of the labour force to over 15.2%–nearly an increas of 12 million migrant workers. The national share of labour in agriculture declines by 3 percentage points. The large reallocation of labour is beneficial for China as a whole; real GDP and welfare rise 4.8% and 8.5%, respectively.

Migrants flow towards higher income regions as the costs of doing so declines. In particular, the coastal provinces of Shanghai, Tianjin, Beijing, and Guangdong are the principle destinations for inter-provincial migrants. Shanghai's employment increases by over 300% in response to our measured change in migration costs, though from a relatively low base compared to the other provinces. In response, real incomes in provinces to which migrants move decline. As these are typically richer regions, regional income differences dramatically decline (by nearly a third). There is similar regional heterogeneity in the effect of migration cost reductions on trade flows. While international and internal trade shares increase by only 0.2 percentage points (so provincial home shares π_{nn}^{j} decline by 0.4 percentage points on average), there are substantial differences between individual provinces. Initially higher income (coastal) regions, which are the destination of migrants, see their trade increase significantly while lower income (interior) regions see decreased volumes.

Finally, we explore changes in migration costs within and between provinces and sectors. Within-province changes (that is, only between agriculture and nonagriculture within provinces) increase welfare by 4.8%. Lower costs of migration between sectors and provinces increase welfare by 2.7%. Overall, the weflare gain from the reductions in costs to rural-urban migration, both within- and between-provinces, is 7.2%, much larger than the gain from the changes in the costs of within-sector, between-province migration. These results are also consisten with those from the back-of-the-evenlope calculation we reported in Section 2.

5.3 Changes in Productivity Parameters

So far we have held the productivity parameters T_n^j constant. Not surprisingly, the implied change in real GDP per worker does not match data. We now calibrate changes $\hat{T}_n^j$ such that, when migration and trade costs decline as measured, the re-

Table 9: Effects of Various Cost and Productivity Parameter Changes

Measured Change for	Trade/GDP Ratio (p.p. Change) Internal	External	Migrant Stock Within Province	Between Province	Aggregate Outcomes GDP per worker	Welfare
Region-Sector Efficiency, $\hat{T}_n^j$	-0.0	-0.0	3.5%	26.8%	43.7%	37.9%
Marginal Effects (changes relative to what productivity delivers)						
Internal Trade	9.1	-0.7	0.8%	-3.8%	10.5%	11.0%
External Trade	-0.6	3.5	4.8%	5.5%	5.0%	1.9%
All Trade	8.2	2.6	5.4%	1.6%	15.5%	12.7%
Migration	0.0	0.2	12.4%	79.7%	6.6%	8.9%
Internal Changes	8.9	-0.5	13.0%	73.1%	17.5%	21.0%
Everything	7.9	2.8	17.8%	82.2%	23.2%	22.6%
No Change in Productivity (consistent with earlier tables)						
Internal Trade	9.2	-0.7	0.8%	-2.0%	10.7%	10.7%
External Trade	-0.7	3.9	1.8%	2.4%	3.8%	2.6%
All Trade	8.2	2.9	2.5%	0.3%	14.4%	13.2%
Migration	0.1	0.2	14.5%	82.4%	4.8%	8.5%
Internal Changes	9.2	-0.6	15.1%	79.3%	15.9%	20.3%
Everything	8.2	3.0	17.0%	84.1%	20.0%	22.8%
Data*	8.2	3.0	22%	131%	77%	–

Notes: Displays aggregate response to various cost changes with and without changes in the region-sector specific efficiency $\hat{T}_n^j$. Marginal effects reflect the changes relative to the equilibrium with only efficiency changes. The migrant stock is the number of workers living outside their province of registration. * The data on trade to GDP ratios is from the model, which matches the region level trade share changes described in Section 2. The region-level data under-reports internal trade by neglecting inter-provincial trade among provinces within the same broader region. Our model (and 2002 data) is at the province-level. The reported change in the migrant stock reflects matching migration shares from the Census perfectly, though differs from Table 1 due to, for example, changes in Hukou registration status that we do not model.

sulting change in real GDP per worker in each province-sector matches data. The changes in T_n^j could be the results of changes in the average efficiency or average capital intensity of the firms in region n and sector j, or the changes in capital allocation among these firms, or some combination of these changes. With the productivity parameters thus calibrated, the model precisely matches $\hat{V}_n^j$ and therefore also $\hat{m}_{ni}^{jk}$.

How do changes in efficiency affect China's economy? We display our main results in Table 9. The first row of this table displays the effect of $\hat{T}_n^j$ alone. Welfare, GDP, and trade volumes all rise significantly, but trade shares change little. Productivity also increases the stock of inter-provincial migrants, with little change in the within-province between-sector migration.

Table 10: Decomposing China's Aggregate Labour Productivity Growth

	Marginal Effects		
	Real GDP per Worker Growth	Share of Growth	Standard Deviation
Overall (All Changes)	57.1%	–	–
Productivity Changes	37.6%	0.66	1.2%
Internal Trade Cost Changes	9.7%	0.17	0.4%
External Trade Cost Changes	4.2%	0.07	0.6%
Migration Cost Changes	5.6%	0.10	0.9%
Of the Migration Cost Changes,			
Between-Province, Within-Nonag	0.9%	0.02	0.4%
Between-Province, Within-Ag	0.0%	0.00	0.0%
Between-Province, Ag-Nonag	3.3%	0.06	0.9%
Within-Province, Ag-Nonag	1.4%	0.03	0.4%

Notes: Decomposes the change in real GDP into contributions from productivity, internal trade cost changes, external trade cost changes, and migration cost changes. The bottom panel decomposes the change due to migration cost changes into various different types of migration. To attribute contributions from each component, we report Shapley Values – or, equivalently, the marginal contribution to aggregate growth of each component across all permutations. In the last column, we report the standard deviation of those growth rates across permutations.

We display the marginal effects of trade and migration costs change, which are the change in the various outcome variables relative to the equilibrium with only productivity changes, in the second panel of Table 9. The marginal effects of changing trade costs are similar to our earlier results, but the impact of changes in migration costs are now smaller. The change in the stock of migrants from lower migration costs is substantially lower than our baseline, and much closer to the level actually observed. The increase in aggregate welfare is now only 4.6% compared to 7.3% when there is no change in underlying productivity. The reason for the lower impacts of the migration cost reductions is that there had been some convergence in the underlying non-agricultural productivity across provinces.

5.4 Decomposing China's Recent Economic Growth

Our model matches data by construction, given the way in which we calibrate changes in a region and sector's productivity parameter T_n^j, so we can decompose

China's overall growth into one of four components: changes in the productivity parameters, lower internal trade costs, lower international trade costs, and lower migration costs. The last component can be further decomposed into between- and within-province changes in migration costs. As the effect of changing one component depends on changes in the other, the order in which each component is introduced matters in evaluating the marginal contribution of one particular component. In Table 10 we report the Shapley Values of each component, with growth rates given as $log(\hat{x})$ for additivity.[9]

Reductions in trade and migration frictions account for two-thirds of China's overall growth. Reductions in internal trade and migration costs contributes roughly one-quarter (15.3% out of the 57.1%). In stark contrast, international trade cost reductions account for only 7% of the overall growth (4.2% out of the 57.1%). Of the contribution from migration cost changes, most is due to lower costs of switching from agricultural to non-agricultural sectors, and in particular for those also migrating across provinces.

We display the standard deviation of each component's effect on GDP in the last column of Table 10. This reflects the extent to which the order of changes matters. As we saw in the previous section, the gains from lowering migration costs are larger when changes in the productivity parameter $\hat{T}_n^j$ are first taken into account. Correspondingly, the gains from productivity improvements are smaller when change in migration costs are introduced first. The interaction effects between them explain why the marginal contribution of these two components vary slightly more across different permutations. Relative to the average, however, the variability of each component's marginal contribution across permutations is small.

Overall, the conterfactual analysis we conducted in this section and the back-of-the-envelope calculation we did in Section 3 yield similar quantitative results. In particular, both methods show that, between 2000 and 2005, internal trade and internal migration contributed much more to China's GDP growth and welfare than international trade did. The additional insights we gained from the analysis using the full model are the following: (1) the increases in trade and migration were

[9] The 77% reported for real GDP growth reported in Table 9 is consistent with the 57.1% reported here, since 0.571=log(1.77).

mainly due to the reductions in trade costs and the migration costs, respectively, and there was little interaction effect between the two types of cost changes, and (2) the gain from the migration cost reductions is smaller than that implied by the back-of-the-envelope calculation due to the land as a fixed fator, the institutional restriction on the rental market of land, and workers' heterogeneous location preferences. In addition, we can also use our model to qunatify potential gains from further reform, to which we turn now.

6 Potential Gains from Further Reform

6.1 Further Reductions in Trade and Migration Costs

Our decomposition shows that reductions in trade and migration frictions and the resulting reduction in misallocation of labour had played a major role in China's growth between 2000 and 2005. How much additional scope is there for further reductions in trade and migration costs?

Let's begin with internal trade costs. We choose Canada since Statistics Canada's internal trade data is superior to the U.S. commodity-flow survey. In particular, Albrecht and Tombe (2016) estimate Canada's internal trade costs separately for a variety of sectors. Reformulating their results to be consistent with our model, we find the trade-weighted average agricultural and nonagricultural trade costs of 94.9% and 149.1%, respectively. For China, the corresponding average internal trade cost in 2007 are 288.3% and 167.0%, respectively. Lowering China's costs to Canada's level would imply $\hat{\tau}_{ni}^{ag} = \frac{1.949}{3.883} = 0.502$ and similarly $\hat{\tau}_{ni}^{na} = 0.933$. Note we change internal trade costs only and hold all else fixed. We simulate these additional changes in trade costs relative to our 2005 counterfactual equilibrium. We report the results in Table 11. We find China's real GDP and welfare could increase by a further 10.9% and 11.8% if average internal trade costs fell to Canada's level.

Next, consider lowering migration costs in China such that migration flows rise substantially above their recent levels. Consider, for example, the United States where the share of individuals living outside of their state of birth is roughly one-third – substantially more than in China. We can explore tha potential gains to China

Table 11: Potential Gains of Further Trade and Migration Liberalization

	Relative to 2005 Eq'm	
	Change in Real GDP	Aggregate Welfare
Average Internal Trade Costs as in Canada	10.9%	11.8%
A One-Third Inter-Provincial Migrant Share	22.8%	15.0%
Both Together	37.0%	30.5%

Notes: Reports the change in real GDP and welfare that result from changing China's internal trade and migration costs such that one third of workers are outside there province of registration (a similar share as the United States). Percentage changes are expressed relative to the 2005 equilibrium.

from lowering migration costs sufficiently to achieve this same one-third share of inter-provincial migrants. We find $\hat{\mu}_{ni}^{jk} = 0.2$ for all $n \neq i$ will deliver this share (note we do not change migration costs within provinces between sectors). The resulting increase in real GDP and welfare is 22.8% and 15.0%, respectively. To be sure, this is not a measure of by how much migration costs are in the United States relative to China. The flow-cost nature of migration costs that makes sense in China may very well not make sense elsewhere, where migration is a more dynamic decision. In any case, there is scope for further migration reform in China and large potential gains from doing so.

6.2 Land Reform

As one of the principal frictions inhibiting labour mobility in China is the nature of land ownership, we briefly explore the effects of alternative land ownership regimes. All our prior analysis involved changing measured trade costs, migration costs, and productivity but ownership of land remained with non-migrant local workers. Now, we explore the effect of land ownership held by those based on registration but hold fixed all other aspects of the model. That is, a worker retains her claims to home region's land income regardless of where she moves.

To perform this exercise, we modify the model to provide workers from (n, j) an equal per-capita rebate $r_n^j S_n^j / \bar{L}_n^j$ regardless of where they live. Previously, only non-migrant locals received this rebate. Thus, migrants gain while non-migrants lose so the equilibrium number of migrants will increase. To solve the new counterfactual

Table 12: Effect of Individual Onwership Land Reform

	% Change	
Welfare	9.6%	
Real GDP	-2.2%	
Migration, Within-Province	65.2%	
Migration, Between-Province	26.6%	
	Share of Population	
	Initial Equilibrium	New Equilibrium
Agricultural Workers	52.9%	56.0%
Stock of Migrants, Urban-Rural	2.1%	8.7%
Stock of Migrants, Rural-Urban	14.0%	17.5%

Notes: Reports the change in various outcomes that results from a counterfactual where workers are permitted to keep land income, regardless of where they live. All workers registered in (n, j) receive an equal per capita land rebate $r_n^j S_n^j / \bar{L}_n^j$, even if they move to another region.

of the model, let $\rho_n^j = r_n^j S_n^j / \bar{L}_n^j$ be the land rebates per registrant of region n and sector j. From section 3.3, we have

$$\delta_{ni}^{jk} = 1 + \frac{(1-\alpha) v_n^j L_n^j + \frac{\eta^j}{\beta^j} w_n^j L_n^j}{w_i^k \bar{L}_n^j}. \tag{14}$$

Migration costs are held constant, so

$$\frac{\hat{m}_{ni}^{jk}}{\hat{m}_{nn}^{jj}} = \left(\frac{\hat{\delta}_{ni}^{jk} \hat{V}_i^k}{\hat{\delta}_{nn}^{jj} \hat{V}_n^j} \right)^{\kappa}, \tag{15}$$

where $\hat{\delta}_{ni}^{jk} = 1 + \rho_n^{j\,\prime} / w_i^{k\,\prime}$ if $n \neq i$ or $j \neq k$ and $\hat{\delta}_{nn}^{jj} = \frac{1 + \rho_n^{j\,\prime} / w_n^{j\,\prime}}{1 + \left(\rho_n^j / m_{nn}^{jj} \right) / w_n^j}$ otherwise. Thus, the first-order effect of land reform is to increase migration disproportionately to regions of low wages from regions of high land income. That is, between pairs where $\rho_n^{j\,\prime} / w_i^{k\,\prime}$ is large, such as from urban areas to rural. To solve the full counterfactual equilibrium is not trivial, but as the nature of the exercise here is clear we only report the results in Table 12 and describe the full algorithm in the Appendix B.

Moving to individual land ownership has a large positive effect on both welfare and the number of migrants, but real GDP falls slightly. As suggested by our earlier derivations, migration will disproportionately increase from urban to rural areas.

This is precisely what we see, with the share of workers working in rural areas but registered in urban ones rising from an initial 2% of the population to nearly 9%. Rural to urban migration, on the other hand, increases less – from 14% to 17.5%. The resulting increase in agricultural workers, and in the weight of relatively low real-GDP regions, accounts for the aggregate drop. Overall, the stock of migrants within provinces increases 65%, and by nearly 27% between provinces. As a result, welfare rises by nearly 10% as more workers are able to live where they prefer, and may take their higher land rebates from urban areas to afford lower cost housing, for example, in rural areas.

7 Conclusion

China experienced rapid GDP growth between 2000 and 2005. There is a widely held belief that the main reason for this rapid growth is the external trade liberalization associated with China's assession to WTO in 2001, and the resulting export expansion supported by a large increase in the supply of cheap migrant workers. Internal policy reforms undertaken by the Chinese government during the same period have not received as much attention. We find these reforms helped reduce the costs of both internal trade and migration. Using a general equilibrium model featuring internal trade, international trade, and worker migration across regions and sectors, we quantify the effect of changes in trade and migration costs on China's aggregate productivity growth and welfare. We find that reductions in internal trade and migration costs account for 27% of the aggregate labour productivity growth in China between 2000 and 2005. In contrast, reductions in external trade costs account for only 7% of the aggregate labour productivity growth during the same period. Despite the reductions, internal trade and migration costs in China are still much higher than those in developed countries such as Canada and the U.S. Further reforms that lower these costs to developed country levels would yield substantial increases in China's aggregate productivity and welfare.

While our results may lead one to conclude international liberalization matters little for aggregate outcomes, we should point out the contribution of trade liberalization that we quantify is the effect of trade-induced resource reallocation. We have shown that internal trade liberalization results in a much larger reallocation effect than external trade liberalization does. However, external trade liberalization may also contribute to productivity growth through other channels that we have not studied in this paper. Two channels that we think are particularly relevant for China are FDI and the associated technology transfers (as in Ramondo and Rodriguez-Clare, 2013) and the influence of international liberalization on internal policy reforms. We leave the study of these issues to future research.

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Appendix

Appendix A provides source and summary information for our main data. Appendix B provides supplementary material not included in the main text.

Appendix A: Data Sources and Summary Statistics

GDP and Employment by Sector and Province – We use official nominal GDP and employment data for agriculture (primary sector) and non-agriculture (secondary and tertiary sectors) available through various Chinese Statistical Yearbooks. We accessed these data through the University of Michigan's China Data Online service (at chinadataonline.org).

Spatial Prices – We measure *real* GDP per worker by province and sector by deflating the official nominal GDP data with the spatial price data of Brandt and Holz (2006). We use the common basket price index for rural areas to deflate agriculture's nominal GDP in each province. Similarly, we use the common basket price index for urban areas to deflate nonagriculture's nominal GDP.

Migration Shares – Using China's 2000 Population Census and 2005 1% Population Survey, we calculate migration shares. Specifically, to measure m_{ni}^{jk}, we calculate the fraction of all employed workers with Hukou registration in region n of type j (agricultural or nonagricultural Hukou) currently working in province i and employed in sector k (agricultural or nonagricultural). Current industry of employment is classified using China's GB2002 classification system. We assign to agricultural all industries with GB2002 codes 01-05.

Trade Shares – We use the regional Input-Output data of Li (2010) to measure the initial equilibrium trade shares π_{ni}^{j} for 2002. The data is disaggregated by sector, with agriculture on its own. We aggregate all other sectors into nonagriculture. The trade share π_{ni}^{j} is the fraction of total spending by region n on goods in sector j sourced from region i. Total expenditure is the sum of final use and intermediates. To measure the change in trade costs between 2002 to 2007, we require data on changes in trade shares from 2002 to 2007. For this, we use the data of Zhang and Qi (2012), which provides similar data as Li (2010) but aggregated to either broad regions. The eight regions are: Northeast (Heilongjiang, Jilin, Liaoning), North Municipalities (Beijing, Tianjin), North Coast (Hebei, Shandong), Central Coast (Jiangsu, Shanghai, Zhejiang), South Coast (Fujian, Guangdong, Hainan), Central (Shanxi, Henan, Anhui, Hubei, Hunan, Jiangxi), Northwest (Inner Mongolia, Shaanxi, Ningxia, Gansu, Qinghai, Xinjiang), and Southwest (Sichuan, Chongqing, Yunnan, Guizhou, Guanxi, Tibet).

Production Shares – These are the share of gross output net of physical capital, since our model abstracts from physical capital. If production technologies are $Y = \tilde{A}H^{\tilde{\beta}}S^{\tilde{\eta}}K^{\tilde{\alpha}}Q^{1-\tilde{\beta}-\tilde{\eta}-\tilde{\alpha}}$, then gross output net of physical capital can be written as $Y = AH^{\beta}S^{\eta}Q^{1-\beta-\eta}$, where $\beta = \tilde{\beta}/(1-\tilde{\alpha})$ and $\eta = \tilde{\eta}/(1-\tilde{\alpha})$. So, the values of β and η can be inferred from the value-added share of gross output, $\tilde{\beta}+\tilde{\eta}+\tilde{\alpha}$, and the factor shares of value-added $\tilde{\beta}/(\tilde{\beta}+\tilde{\eta}+\tilde{\alpha})$, $\tilde{\eta}/(\tilde{\beta}+\tilde{\eta}+\tilde{\alpha})$, and $\tilde{\alpha}/(\tilde{\beta}+\tilde{\eta}+\tilde{\alpha})$. For value-added's shares of gross output, we calculate them directly from China's Input-Output table, which turns out to average around 0.59 in agriculture and 0.35 in nonagriculture. For factor shares of value-added, we do not use the Chinese data because: (1) There are significant factor market distortions in China so that reported factor shares do not necessarily equal the corresponding factor elasticities in the production function; and (2) there is no separate reporting of spending on land due to a lack of private land ownership–it is implicitly included in the reported spending on labour in agriculture and reported spending on capital in non-agriculture. To avoid these problems, we instead use the sector-specific factor shares of value-added for the US as reported in Caselli and Coleman (2001). Specifically, they report labour's share of 0.6 in both sectors. Land's share is 0.19 in agriculture and 0.06 in nonagriculture. Capital's share is therefore 0.21 in agriculture and 0.34 in nonagriculture. Based on these, we have $\tilde{\beta}^{ag} = 0.60 \times 0.59 = 0.354$ and similarly $\tilde{\beta}^{na} = 0.21$, $\tilde{\eta}^{ag} = 0.1121$, $\tilde{\eta}^{na} = 0.021$, $\tilde{\alpha}^{ag} = 0.1239$, and $\tilde{\alpha}^{na} = 0.119$. Thus, we have our main parameter values $\beta^{ag} = 0.354 \div (1-0.1239) = 0.404$ and similarly $\beta^{na} = 0.238$, $\eta^{ag} = 0.128$, and $\eta^{na} = 0.024$.

For input-output shares, we further rely on this data**.** Overall, nonagricultural inputs are 0.25 of agricultural gross output and 0.61 of nonagricultural gross output. Further, agricultural inputs are 0.16 of agricultural gross output and 0.04 of nonagriculture. Thus,

$$\sigma^{jk} = \begin{bmatrix} 0.16 & 0.25 \\ 0.04 & 0.61 \end{bmatrix},$$

where the first row are the input shares for agriculture, from agriculture and nonagriculture respectively, and the second row are the input shares for nonagriculture.

Selected Summary Statistics, by Province – In the following tables, we report various summary measures of trade, real incomes, migration, employment, and other metrics for all provinces and sectors.

Table 13: Summary Data for China's Provinces, 2000

Province	Employment (millions)	Inter-Provincial Migrant Share of Employment	Intra-Provincial Migrant Share of Employment	Agriculture's Share of Employment	Relative Real Ag. Income	Relative Real Nonag. Income	Home Bias in Total Trade	International Export Share of Production
Anhui	33.73	0.004	0.113	0.60	0.31	1.09	0.619	0.024
Beijing	6.22	0.231	0.147	0.12	0.63	1.89	0.661	0.065
Chongqing	16.37	0.014	0.112	0.57	0.30	1.25	0.545	0.020
Fujian	16.60	0.077	0.285	0.47	0.64	1.99	0.807	0.118
Gansu	11.82	0.009	0.056	0.60	0.22	1.06	0.776	0.039
Guangdong	38.61	0.270	0.193	0.41	0.40	1.68	0.647	0.239
Guangxi	25.30	0.008	0.087	0.62	0.27	1.02	0.694	0.027
Guizhou	20.46	0.012	0.069	0.67	0.14	0.69	0.718	0.017
Hainan	3.34	0.051	0.150	0.61	0.67	1.13	0.624	0.031
Hebei	34.41	0.013	0.144	0.49	0.47	1.57	0.718	0.023
Heilongjiang	16.35	0.012	0.107	0.49	0.38	2.19	0.797	0.026
Henan	55.72	0.004	0.079	0.64	0.30	1.32	0.875	0.013
Hubei	25.08	0.011	0.127	0.48	0.45	1.65	0.857	0.016
Hunan	34.62	0.005	0.109	0.61	0.27	1.27	0.849	0.016
Inner Mongolia	10.17	0.023	0.123	0.54	0.55	1.41	0.775	0.020
Jiangsu	35.59	0.039	0.252	0.42	0.55	2.05	0.802	0.100
Jiangxi	19.35	0.006	0.140	0.52	0.41	1.01	0.790	0.015
Jilin	10.79	0.011	0.083	0.50	0.66	1.72	0.554	0.025
Liaoning	18.13	0.024	0.131	0.38	0.66	2.16	0.827	0.063
Ningxia	2.74	0.034	0.124	0.58	0.24	1.20	0.633	0.014
Qinghai	2.39	0.024	0.064	0.61	0.23	1.51	0.640	0.038
Shandong	46.62	0.011	0.152	0.53	0.44	1.95	0.830	0.060
Shanghai	6.73	0.240	0.168	0.13	0.49	3.39	0.645	0.179
Shaanxi	18.13	0.010	0.115	0.56	0.21	1.01	0.758	0.001
Shanxi	14.19	0.019	0.168	0.47	0.22	1.09	0.858	0.036
Sichuan	44.36	0.005	0.095	0.60	0.32	1.08	0.881	0.020
Tianjin	4.07	0.080	0.157	0.20	0.59	2.64	0.552	0.153
Xinjiang	6.72	0.095	0.098	0.58	0.59	2.40	0.757	0.025
Yunnan	22.95	0.028	0.080	0.74	0.17	1.54	0.807	0.017
Zhejiang	27.00	0.096	0.408	0.38	0.51	1.75	0.743	0.094

Notes: Reports various provincial characteristics in 2000. Employment and GDP data are from official sources, deflated using spatial price indexes. Migration data is constructed from the 2000 Population Census. See text for details. The last two columns use 2002 data on trade flows. Home-bias reports total production for domestic use as a share of total absorption (calculated as 1/(1+I/D), where I is total imports and D is gross output less total exports).

Appendix B: Supplementary Material

In this Appendix, we provide (1) the proofs for all main propositions, (2) details behind relative changes in key model variables that were not provided in the main text, (3) details behind estimating the Head-Ries method of estimating trade costs adjusted for asymmetries, and (4) various robustness exercises and alternative model specifications.

Proofs of Propositions

Proposition 1: *Given real incomes for each region and sector V_i^k, migration costs between all regional pairs μ_{ni}^{jk}, adjustments for land rebates δ_{ni}^{jk}, and idiosyncratic preferences distributed $F_z(x)$, the share of (n,j) workers that migrate to (i,k) is*

$$m_{ni}^{jk} = \frac{\left(V_i^k \delta_{ni}^{jk} / \mu_{ni}^{jk}\right)^{\kappa}}{\sum_{k'} \sum_{i'} \left(V_{i'}^{k'} \delta_{ni'}^{jk'} / \mu_{ni'}^{jk'}\right)^{\kappa}}.$$

Proof: The share of people from (n,j) that migrate to (i,k) is the probability that each individual's utility in (i,k) exceeds that in any other region. Specifically,

$$m_{ni}^{jk} \equiv Pr\left(V_i^k \delta_{ni}^{jk} z_i^k / \mu_{ni}^{jk} \geq \max_{i',k'} \left\{ z_{i'}^{k'} \delta_{ni'}^{jk'} V_{i'}^{k'} / \mu_{ni'}^{jk'} \right\}\right).$$

Since $Pr\left(z_i^k \leq x\right) \equiv e^{-(\tilde{\gamma}x)^{-\kappa}}$ by assumption of Frechet distributed worker preferences, we have $Pr\left(V_i^k \delta_{ni}^{jk} z_i^k / \mu_{ni}^{jk} \leq x\right) = Pr\left(z_i^k \leq x\mu_{ni}^{jk} / V_i^k \delta_{ni}^{jk}\right) = e^{-\left(x/\phi_{ni}^{jk}\right)^{-\kappa}}$ where $\phi_{ni}^{jk} = V_i^k \delta_{ni}^{jk} / \mu_{ni}^{jk} \tilde{\gamma}$ The distribution of net income across workers from (n,j) in (i,k) is therefore also Frechet. Similarly, the distribution of the highest net real income in all other regions is described by

$$\begin{aligned}
Pr\left(\max_{k' \neq k, i' \neq i} \left\{ z_{i'}^{k'} V_{i'}^{k'} \delta_{ni'}^{jk'} / \mu_{ni'}^{jk'} \right\} \leq x\right) &= \prod_{k' \neq k} \prod_{i' \neq i} Pr\left(z_{i'}^{k'} V_{i'}^{k'} \delta_{ni'}^{jk'} / \mu_{ni'}^{jk'} \leq x\right), \\
&= \prod_{k' \neq k} \prod_{i' \neq i} Pr\left(z_{i'}^{k'} \leq x\mu_{ni'}^{jk'} / V_{i'}^{k'} \delta_{ni'}^{jk'}\right), \\
&= \prod_{k' \neq k} \prod_{i' \neq i} e^{-\left(\tilde{\gamma} x \mu_{ni'}^{jk'} / V_{i'}^{k'} \delta_{ni'}^{jk'}\right)^{-\kappa}}, \\
&= e^{-x^{-\kappa} \sum_{k' \neq k} \sum_{i' \neq i} \left(\tilde{\gamma} \mu_{ni'}^{jk'} / V_{i'}^{k'} \delta_{ni'}^{jk'}\right)^{-\kappa}}, \\
&= e^{-\left(x/\Phi_n^j\right)^{-\kappa}},
\end{aligned}$$

which is also Frechet, where $\Phi_n^j = \left(\sum_{k' \neq k} \sum_{i' \neq i} \left(V_{i'}^{k'} \delta_{ni'}^{jk'} / \tilde{\gamma} \mu_{ni'}^{jk'}\right)^{\kappa}\right)^{1/\kappa}$.

Returning to the original m_{ni}^{jk} expression, let $X = V_i^k \delta_{ni}^{jk} z_i^k / \mu_{ni}^{jk}$ and $Y = \max_{k' \neq k, i' \neq i} \left\{ z_{i'}^{k'} V_{i'}^{k'} \delta_{ni'}^{jk'} / \mu_{ni'}^{jk'} \right\}$, which are Frechet distributed with parameters $s_X = \phi_{ni}^{jk}$ and $s_Y = \Phi_n^j$, respectively. By the Law of Total Probability,

$$
\begin{aligned}
m_{ni}^{jk} &= \int_0^\infty Pr\left(X \geq Y \mid Y = y\right) f_Y(y) dy, \\
&= \int_0^\infty \left(1 - e^{-(y/s_X)^{-\kappa}}\right) \kappa s_Y^\kappa y^{-1-\kappa} e^{-(y/s_Y)^{-\kappa}} dy, \\
&= 1 - \int_0^\infty e^{-(s_X^\kappa + s_Y^\kappa) y^{-\kappa}} \kappa s_Y^\kappa y^{-1-\kappa} dy,
\end{aligned}
$$

With a change of variables $u = y^{-\kappa}$ and therefore $du = -\kappa y^{-\kappa-1} dy$,

$$
\begin{aligned}
m_{ni}^{jk} &= 1 + \int_{u=\infty}^{u=0} e^{-(s_X^\kappa + s_Y^\kappa) u} s_X^\kappa du, \\
&= 1 - s_Y^\kappa \int_0^\infty e^{-(s_X^\kappa + s_Y^\kappa) u} du, \\
&= 1 - \frac{s_Y^\kappa}{s_X^\kappa + s_Y^\kappa} = \frac{\left(V_i^k \delta_{ni}^{jk} / \mu_{ni}^{jk}\right)^\kappa}{\sum_{k'} \sum_{i'} \left(V_{i'}^{k'} \delta_{ni'}^{jk'} / \mu_{ni'}^{jk'}\right)^\kappa},
\end{aligned}
$$

which is the result. ■

Proposition* 2*: *Given changes in migration and real incomes, the change aggregate welfare is*

$$
\hat{W} = \sum_j \sum_{n=1}^N \omega_n^j \hat{V}_n^j \hat{m}_{nn}^{j\ -1/\kappa},
$$

where $\omega_n^j \propto \bar{L}_n^j V_n^j m_{nn}^{j\ -1/\kappa}$ *is region n and sector j's initial contribution to welfare.*

Similarly, the change in real GDP is

$$
\hat{Y} = \sum_j \sum_{n=1}^N \phi_n^j \hat{V}_n^j \hat{L}_n^j,
$$

where $\phi_n^j \propto V_n^j L_n^j$ *is the contribution of region n and sector j to initial real GDP.*

Proof: A worker from (n, j) has different preferences for each potential region and sector in China. Building on the results of Proposition **1**, the probability that a given worker's welfare is below x is the probability that *no* region-sector pair gives utility above x. As $Pr\left(V_i^k \delta_{ni}^{jk} z_i^k / \mu_{ni}^{jk} \leq x\right) = e^{-\left(x/\phi_{ni}^{jk}\right)^{-\kappa}}$, the probability that all region-sector pairs are below x gives the distribution of welfare of workers from (n, i). That is,

$$
F_{U_n^j}(x) = \prod_k \prod_i e^{-\left(x/\phi_{ni}^{jk}\right)^{-\kappa}} = e^{-\left(x/\Phi_n^j\right)^{-\kappa}},
$$

where $\Phi_n^j = \left(\sum_k \sum_i \left(V_{i'}^{k'} \delta_{ni'}^{jk'} / \tilde{\gamma}\mu_{ni'}^{jk'}\right)^{\kappa}\right)^{1/\kappa}$.

To get our result, note that if $Pr(X < x) \equiv F(x) = e^{-(\tilde{\gamma}x/s)^{-\kappa}}$ then $E[X] = s$. So, the utility of workers from (n,i) after migration decisions – distributed according to $F_{U_n^j}(x)$ above – is Frechet with $E\left[U_n^j\right] = \Phi_n^j$. Given that the distribution of idiosyncratic preferences across regions and sectors has mean zero, real income and welfare are synonymous and therefore $\bar{V}_n^j \equiv E\left[U_n^j\right]$. From Proposition 1, $m_{ni}^{jk} = \frac{\left(V_i^k \delta_{ni}^{jk} / \mu_{ni}^{jk}\right)^{\kappa}}{\sum_{k'} \sum_{i'} \left(V_{i'}^{k'} \delta_{ni'}^{jk'} / \mu_{ni'}^{jk'}\right)^{\kappa}}$ and therefore $\bar{V}_n^j = V_n^j \left(m_{nn}^{jj}\right)^{-1/\kappa}$. Aggregate welfare is the mean across all regions of registration, weighted by registration population shares $\lambda_n^j = \bar{L}_n^j / \left(\sum_{n'} \sum_{j'} \bar{L}_{n'}^{j'}\right)$, given by $W = \sum_n \sum_j \lambda_n^j V_n^j \left(m_{nn}^{jj}\right)^{-1/\kappa}$. Taking the ratio of counterfactual W' to initial W yields

$$
\begin{aligned}
\hat{W} &= \frac{\sum_n \sum_j \lambda_n^j V_n^{j\,\prime} \left(m_{nn}^{jj\,\prime}\right)^{-1/\kappa}}{\sum_n \sum_j \lambda_n^j V_n^j \left(m_{nn}^{jj}\right)^{-1/\kappa}}, \\
&= \sum_n \sum_j \omega_n^j \hat{V}_n^j \left(\hat{m}_{nn}^{jj}\right)^{-1/\kappa},
\end{aligned}
$$

where $\omega_n^j = \left(\lambda_n^j V_n^j \left(m_{nn}^{jj}\right)^{-1/\kappa}\right) / \left(\sum_n \sum_j \lambda_n^j V_n^j \left(m_{nn}^{jj}\right)^{-1/\kappa}\right)$, which is our result.

Next, consider the change in real GDP. The derivation is simple as we construct it in a way that matches how we measure it in the data. Nominal GDP in region n and sector j is $(\eta^j + \beta^j)R_n^j + r_n^j S_n^j = w_n^j L_n^j$ (since trade balances). Then let real GDP be this nominal GDP deflated by the overall price index $\left(P_n^{ag\,\varepsilon} P_n^{na\,1-\varepsilon}\right)^{\alpha} r_n^{j\,1-\alpha}$. Since $\hat{r}_n^j = \hat{w}_n^j \hat{L}_n^j$, the change in real GDP in (n,j) is $\left(\hat{w}_n^j \hat{L}_n^j / \hat{P}_n^{ag\,\varepsilon} \hat{P}_n^{na\,1-\varepsilon}\right)^{\alpha}$ or $\hat{V}_n^j \hat{L}_n^j$. Thus, the aggregate change in real GDP is

$$
\hat{Y} = \sum_j \sum_{n=1}^{N} \phi_n^j \hat{V}_n^j \hat{L}_n^j,
$$

where $\phi_n^j \propto V_n^j L_n^j$ is the contribution of (n,j) to initial national real GDP.■

Relative Changes in Key Variables

Equations 3, 4 and 5 imply

$$\hat{c}^j_{ni} = \hat{w}^{j\,\beta^j}_i \hat{r}^{j\,\eta^j}_i \left(\prod_{k\in\{ag,na\}} \hat{P}^{k\,\sigma^{jk}}_i\right), \tag{16}$$

$$\hat{\pi}^j_{ni} = \frac{\hat{T}^j_i \left(\hat{\tau}^j_{ni}\hat{c}^j_i\right)^{-\theta}}{\sum_{m=1}^{N+1} \pi^j_{nm}\hat{T}^j_m \left(\hat{\tau}^j_{nm}\hat{c}^j_m\right)^{-\theta}}, \tag{17}$$

$$\hat{P}^j_n = \left[\sum_{m=1}^{N+1} \pi^j_{nm}\hat{T}^j_m \left(\hat{\tau}^j_{nm}\hat{c}^j_m\right)^{-\theta}\right]^{-1/\theta}. \tag{18}$$

Given $\pi^{j\,'}_{ni} = \hat{\pi}^j_{ni}\pi^j_{ni}$, equations 2, 6 and 7 solve counterfactual expenditures $X^{j\,'}_{ni}$, revenues $R^{j\,'}_{ni}$, and incomes $\sum_j v^{j\,'}_n L^{j\,'}_n$. We therefore know $\hat{w}^j_n = \hat{R}^j_n/\hat{L}^j_n$ and $\hat{r}^j_n = \hat{R}^j_n$. All together, these expressions give changes in prices $\hat{P}^j_n$, trade flows $\hat{\pi}^j_{ni}$, and wages $\hat{w}^j_n$ per effective worker as a function of changes in trade costs ($\hat{\tau}^j_{ni}$), underlying productivity ($\hat{T}^j_n$), and employment ($\hat{L}^j_n$). It remains to solve for changes in migration flows. As the change in real incomes isn

$$\hat{V}^j_n = \frac{\hat{w}^{j\,\alpha}_n}{\left(\hat{P}^{ag\,\varepsilon}_n \hat{P}^{na\,1-\varepsilon}_n\right)^{\alpha} \hat{L}^{j\,1-\alpha}_n}, \tag{19}$$

which, given exogenous changes in migration costs $\hat{\mu}^{jk}_{ni}$, changes in migration shares are

$$\hat{m}^{jk}_{ni} = \frac{\left(\hat{\delta}^{jk}_{ni}\hat{V}^k_i/\hat{\mu}^{jk}_{ni}\right)^{\kappa}}{\sum_k \sum_{i'=1}^{N} m^{jk'}_{ni'}\left(\hat{\delta}^{jk'}_{ni'}\hat{V}^{k'}_{i'}/\hat{\mu}^{jk'}_{ni'}\right)^{\kappa}}. \tag{20}$$

These shares then imply $L^{j\,'}_n = \sum_{i,k} m^{kj\,'}_{in}\bar{L}^k_i$ and, from equation 9, $\hat{\delta}^{jk}_{ni}$.

Solving for Equilibrium Changes due to Land Reform

To solve the model for counterfactual changes in land ownership, we modify the model to provide workers from (n,j) an equal per-capita rebate $r^j_n S^j_n/\bar{L}^j_n$ regardless of where they live. Previously, only non-migrant locals received this rebate. Thus, migrants gain while non-migrants lose so the equilibrium number of migrants will increase. To solve the new counterfactual of the model, let $\rho^j_n = r^j_n S^j_n/\bar{L}^j_n$ be the land rebates per registrant of region n and sector j. From section 3.3, we have

$$\delta^{jk}_{ni} = 1 + \frac{(1-\alpha)v^j_n L^j_n + \frac{\eta^j}{\beta^j} w^j_n L^j_n}{w^k_i \bar{L}^j_n}. \tag{21}$$

Migration costs are held constant, so

$$\frac{\hat{m}_{ni}^{jk}}{\hat{m}_{nn}^{jj}} = \left(\frac{\hat{\delta}_{ni}^{jk}\hat{V}_i^k}{\hat{\delta}_{nn}^{jj}\hat{V}_n^j}\right)^{\kappa}, \tag{22}$$

where $\hat{\delta}_{ni}^{jk} = 1 + \rho_n^{j\,\prime}/w_i^{k\,\prime}$ if $n \neq i$ or $j \neq k$ and $\hat{\delta}_{nn}^{jj} = \frac{1+\rho_n^{j\,\prime}/w_n^{j\,\prime}}{1+\left(\rho_n^j/m_{nn}^{jj}\right)/w_n^j}$ otherwise. Thus, the first-order effect of land reform is to increase migration disproportionately to regions of low wages from regions of high land income. That is, between pairs where $\rho_n^{j\,\prime}/w_i^{k\,\prime}$ is large, such as from urban areas to rural.

To solve equilibrium aggregate outcomes, begin with total income in region n and sector j as

$$v_n^{j\,\prime} L_n^{j\,\prime} = w_n^{j\,\prime} L_n^{j\,\prime} + \sum_{i,k} \rho_i^{k\,\prime} m_{in}^{kj\,\prime} \bar{L}_i^{k\,\prime}. \tag{23}$$

With this, we solve counterfactual spending, incomes, prices, and so on, largely as before. In particular, equations 2, 6 and 7 combine to yield

$$w_n^{j\,\prime} L_n^{j\,\prime} = \beta^j \sum_{i=1}^{N+1} \pi_{ni}^{jk\,\prime} \left[\alpha\varepsilon^j \sum_k v_n^{k\,\prime} L_n^{k\,\prime} + \sum_k \frac{\sigma^{kj}}{\beta^k} w_n^{k\,\prime} L_n^{k\,\prime}\right]. \tag{24}$$

It remains to solve for counterfactual land incomes. As before, $r_n^{j\,\prime} S_n^{j\,\prime} = (1-\alpha) v_n^{j\,\prime} L_n^{j\,\prime} + \frac{\eta^j}{\beta^j} w_n^{j\,\prime} L_n^{j\,\prime}$ but, unlike before, the right-side of this expression is no longer proportional to wages. But, given $v_n^{j\,\prime}$, $w_n^{j\,\prime}$, $L_n^{j\,\prime}$, and the initial equilibrium, we have $\hat{r}_n^j$. From equations 16 to 18, we then solve for counterfactual prices $\hat{P}_n^j$ and trade shares $\hat{\pi}_{ni}^{jk}$. Given the new trade shares, equations 23 and 24 solve $v_n^{j\,\prime}$ and $w_n^{j\,\prime}$. With these, the new prices for goods and housing, equations 21 and 22 imply new labour allocations $L_n^{j\,\prime}$. Thus we have an algorithm to solve the new equilibrium in full.

Estimating Trade Costs

We begin with a standard Head-Ries index of trade costs. From equation 13 and our data on trade shares, we estimate $\bar{\tau}_{ni}^{j}$. We summarize the average values of this for various bilateral trade flows between regions of China. A value of $\bar{\tau}_{ni}^{j} = 1$ implies zero trade costs and $\bar{\tau}_{ni}^{j} = 2$ implies trade costs equivalent to a 100% tariff-equivalent trade costs. Overall, we find the trade-weighted average trade cost between regions of China is 300% in agriculture and 200% in nonagriculture. Care must be taken when interpreting these values, however, as they reflect trade costs between regions *relative to trade costs within each region* – after all, we normalize $\tau_{nn}^{j} = 1$ for all n and j.

Table 14: Initial Bilateral Trade Costs (Year 2002)

	Exporter								
Importer	North-east	Beijing Tianjin	North Coast	Central Coast	South Coast	Central Region	North-west	South-west	Abroad
Trade Costs in Agriculture, τ_{ni}^{ag}									
Northeast		4.13	3.31	8.28	4.06	3.24	2.09	4.22	2.89
Beijing/Tianjin	2.59		2.08	7.30	4.42	2.89	2.00	4.74	1.99
North Coast	3.40	3.40		6.89	4.18	2.87	2.29	4.53	3.28
Central Coast	3.99	5.60	3.24		3.25	1.83	2.56	4.06	1.84
South Coast	4.89	8.48	4.91	8.11		3.21	3.14	4.04	2.52
Central Region	3.58	5.08	3.10	4.20	2.95		2.33	3.55	4.27
Northwest	2.96	4.51	3.17	7.53	3.70	2.98		3.70	4.49
Southwest	4.34	7.78	4.55	8.67	3.46	3.31	2.69		4.41
Abroad	5.94	6.51	6.56	7.82	4.30	7.93	6.51	8.79	
Trade Costs in Nonagriculture, τ_{ni}^{na}									
Northeast		2.58	2.84	3.63	2.65	3.34	2.69	3.27	3.48
Beijing/Tianjin	2.60		1.92	3.13	2.42	3.09	2.71	3.41	2.93
North Coast	2.78	1.87		2.69	2.48	2.57	2.56	3.56	3.30
Central Coast	3.79	3.24	2.86		2.15	2.35	2.72	3.26	2.49
South Coast	3.73	3.38	3.56	2.90		3.02	3.07	2.89	2.63
Central Region	3.16	2.91	2.48	2.13	2.03		2.48	3.07	4.06
Northwest	3.02	3.03	2.93	2.93	2.46	2.95		2.82	4.63
Southwest	3.09	3.20	3.43	2.95	1.94	3.07	2.37		4.23
Abroad	4.86	4.05	4.69	3.33	2.61	5.98	5.73	6.24	

Note: Displays bilateral trade cost (relative to within-region costs) for agriculture and nonagriculture for eight broad regions. The eight regions are classified as: Northeast (Heilongjiang, Jilin, Liaoning), North Municipalities (Beijing, Tianjin), North Coast (Hebei, Shandong), Central Coast (Jiangsu, Shanghai, Zhejiang), South Coast (Fujian, Guangdong, Hainan), Central (Shanxi, Henan, Anhui, Hubei, Hunan, Jiangxi), Northwest (Inner Mongolia, Shaanxi, Ningxia, Gansu, Qinghai, Xinjiang), and Southwest (Sichuan, Chongqing, Yunnan, Guizhou, Guanxi, Tibet).

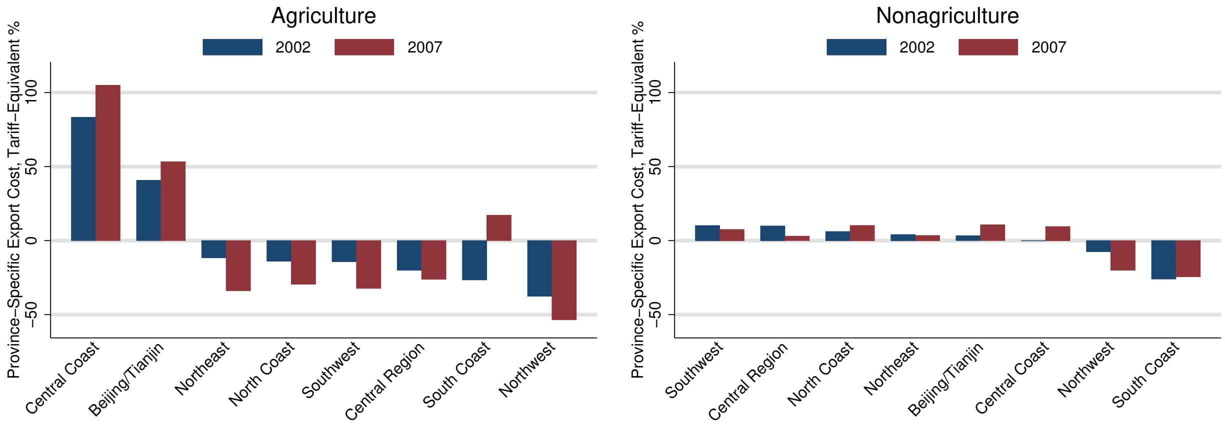
To arrive at our preferred estimate of trade costs τ_{ni}^{j}, we must augment the Head-Ries index $\bar{\tau}_{ni}^{j}$ to reflect trade cost asymmetries. As discussed in the main text, given an exporter-specific trade cost t_i^j, we have $\tau_{ni}^{j} = \bar{\tau}_{ni}^{j}\sqrt{t_i^j/t_n^j}$. How do we estimate these export costs? Within the same class of models for which the Head-Ries estimate holds, a normalized measure of trade flows is

$$ln\left(\pi_{ni}^{j}/\pi_{nn}^{j}\right) = S_i^j - S_n^j - \theta ln\left(\tau_{ni}^{j}\right),$$

where S captures any country-specific factor affecting competitiveness, such as factor prices or productivity. See Head and Mayer (2014) for details behind this and related gravity regressions.

If trade costs have only a symmetric and exporter-specific component, and if the symmetric

Figure 3: Asymmetries in Trade Costs: Exporter-Specific Costs



Notes: Displays the tariff-equivalent (in percentage points) region-specific export costs. All expressed relative to the average for the year. A value of 10 implies exporting is 10 percent more costly relative to the average region.

component is well proxied by geographic distance, then we can estimate t_i^j from

$$ln\left(\pi_{ni}^j/\pi_{nn}^j\right) = \delta^j ln\left(d_{ni}\right) + \iota_n^j + \eta_i^j + \varepsilon_{ni}^j, \tag{25}$$

where δ^j is the distance-elasticity of trade costs, d_{ni} is the (population-weighted) geographic distance between region n and i, and ι_n^j and η_i^j are sector-specific importer- and exporter-effects. Distance between China's provinces and the world is the distance between each region and all other countries weighted by total trade between China and each other country. As the exporter effect is $\hat{\eta}_i^j = S_i^j - \theta ln\left(t_i^j\right)$ and the importer effect is $\hat{\iota}_n^j = -S_n^j$, we infer export costs as $ln\left(\hat{t}_n^j\right) = -\left(\hat{\iota}_n^j + \hat{\eta}_n^j\right)/\theta$.

We use the regional input-output data described in the previous section to estimate this regression. We find distance-elasticities in line with international trade results; specifically, $\hat{\delta}^{ag} = -1.33$ and $\hat{\delta}^{na} = -1.06$ for 2007 with standard errors of 0.38 and 0.22, respectively. For the 2002 trade data, we find $\hat{\delta}^{ag} = -1.43$ and $\hat{\delta}^{na} = -1.04$ with standard errors of 0.41 and 0.28. Finally, we display the estimates of $ln\left(\hat{t}_n\right)$ for both 2002 and 2007 in Figure 3. As the overall level of export costs is undetermined, we express values relative to the mean across all regions within each year. Overall, it is more costly for poor regions to export nonagricultural goods than rich regions – consistent with international evidence from Waugh (2010). For agriculture, this pattern is less clear. There were also very few changes to the ranking across regions in trade cost asymmetries between 2002 and 2007.

Common Proportional Rebates

Instead of rebating land income to local non-migrants within a given region and sector, we now presume all workers receive the same proportional rebate. They receive this rebate regardless of where they live. The adjustments to the model are straightforward.

First, households receive income from wages w_n^j and transfers from the central government, who rebates all earnings from the fixed factor in proportion ρ to labour income. Nominal income per worker is therefore $v_n^j = \rho w_n^j$. Given a sector's total revenue R_n^j and total household income $L_n^j v_n^j$, demand for the fixed factor is $(1-\alpha)L_n^j v_n^j + \eta^j R_n^j$. Given a total endowment of S_n^j, we have $r_n^j S_n^j = (1-\alpha)L_n^j v_n^j + \eta^j R_n^j$. Equivalently,

$$r_n^j = \left((1-\alpha)\rho + \eta^j/\beta^j\right)\frac{w_n^j L_n^j}{S_n^j}. \tag{26}$$

To ensure migration decisions do not depend on rebates, we presume they are proportional to labour income. Requiring all fixed-factor payments are rebated pins down ρ with $\sum_{n,j}(\rho-1)\,w_n^j L_n^j = \sum_{n,j} S_n^j r_n^j$ and therefore

$$\rho = \frac{1}{\alpha}\left[1+\sum_{n,j}\frac{\eta^j}{\beta^j}\frac{w_n^j L_n^j}{\sum_{n,j} w_n^j L_n^j}\right]. \tag{27}$$

Alternatively, if fixed-factor income were rebated only to workers within each region and sector, then $\rho^j = (\beta^j+\eta^j)/\alpha\beta^j$. So the two approaches differ only to the extent that β^j and η^j differ across sectors. We model have equal proportional rebates to all workers so migration decisions are unaffected. That is, we do not allow workers to chase rebates, only wages. We turn now to formalalizing worker migration decisions.

Second, consider migration decisions. Workers then choose where to live to maximize their welfare $\varepsilon_i^k V_i^k/\mu_{ni}^{jk}$. The only difference from our baseline formulation is that δ_{ni}^{jk} is absent. Given real incomes for each region and sector, V_i^k, migration costs between all region-sector pairs μ_{ni}^{jk}, and heterogeneous preferences distributed $F_z(x)$, the share of (n,j)-workers that migrate to (i,k) is

$$m_{ni}^{jk} = \frac{\left(V_i^k/\mu_{ni}^{jk}\right)^{\kappa}}{\sum_k\sum_{m=1}^N\left(V_m^j/\mu_{nm}^{jk}\right)^{\kappa}}, \tag{28}$$

and total employment is $L_n^j = \sum_k\sum_{i=1}^N m_i^k \bar{L}_i^k$.

Finally, the calibration changes in one small way. To get initial real income per worker V_n, we use data on real GDP per worker by province and sector (as before) but rescaled in a particular way. Specifically, it is straightforward to show $V_n^j = \left(\frac{\rho\beta^j}{\beta^j+\eta^j+(1-\alpha)\rho\beta^j}\right)\left(\frac{Y_n^j}{L_n^j}\right)$, where $\left(\frac{Y_n^j}{L_n^j}\right)$ is real per GDP per worker.

With these changes, we simulate our main experiments and display the results in Table 15. Comparing the original results in the first panel with the alternative results in the second panel, it is clear equal-proportional rebates to all workers, versus rebates only to non-migrant locals, changes little. Of course, our migration costs estimates are much higher under this alternative specification, as what was previously classified as lost land income for migrants is now captured directly as a migration cost.

Table 15: Results Under Alternative Specifications

Measured Change for	p.p. Change in Share of Internal Trade	External Trade	Ag. Emp.	Migrant Stock Within Province	Between Province	Aggregate Outcomes Real GDP	Welfare
Baseline Model: Homothetic Preference, I/O Links, No Land Income for Migrants							
Internal Trade	9.2	-0.7	0.0	0.8%	-2.0%	10.7%	10.7%
External Trade	-0.7	3.9	-0.5	1.8%	2.4%	3.8%	2.6%
All Trade	8.2	2.9	-0.4	2.5%	0.3%	14.4%	13.2%
Migration	0.1	0.2	-3.0	14.5%	82.4%	4.8%	8.5%
Internal Changes	9.2	-0.6	-2.9	15.1%	79.3%	15.9%	20.3%
Everything	8.2	3.0	-3.5	17.0%	84.1%	20.0%	22.8%
Homothetic Preference, I/O Links, Equal-Proportional Rebates of Land Income to All							
Internal Trade	9.2	-0.7	0.0	0.8%	-2.0%	10.7%	10.8%
External Trade	-0.7	3.9	-0.5	1.9%	2.4%	3.7%	2.7%
All Trade	8.2	2.9	-0.4	2.5%	0.3%	14.3%	13.5%
Migration	0.1	0.2	-3.0	14.3%	81.9%	4.8%	6.2%
Internal Changes	9.2	-0.6	-2.9	14.9%	78.7%	15.9%	17.9%
Everything	8.2	3.0	-3.5	16.8%	83.6%	19.8%	20.5%
Homothetic Preferences, no I/O Links, Equal-Proportional Rebates of Land Income to All							
Internal Trade	9.2	-0.8	-0.1	1.2%	-1.8%	11.0%	11.0%
External Trade	-0.6	3.9	-0.6	2.3%	2.7%	3.7%	2.6%
All Trade	8.2	2.8	-0.8	3.6%	1.1%	14.6%	13.3%
Migration	0.0	0.1	-3.1	14.8%	82.6%	5.5%	6.7%
Internal Changes	9.1	-0.7	-3.2	15.9%	79.4%	16.9%	18.5%
Everything	8.2	2.9	-4.1	18.6%	85.3%	20.9%	20.7%
Non-Homothetic Preferences, I/O Links, Equal-Proportional Rebates of Land Income to All							
Internal Trade	9.0	-0.7	-0.7	3.6%	-0.1%	11.1%	12.4%
External Trade	-0.6	3.7	-0.9	3.4%	3.9%	4.6%	2.0%
All Trade	8.1	2.7	-1.4	6.6%	3.5%	15.6%	14.4%
Migration	0.0	0.2	-2.3	12.9%	71.2%	3.1%	7.1%
Internal Changes	9.0	-0.5	-3.0	16.3%	70.9%	14.5%	20.5%
Everything	8.1	2.9	-3.9	19.3%	77.3%	19.5%	22.5%

Notes: Displays the main counterfactual experiments under various alternative specifications.

Non-Homoethetic Preferences

With equal-proportional rebates to all workers, we can introduce one additional modification to the model: non-homothetic preferences.

As the choice between agricultural and non-agricultural employment is a critical dimension of our model, we explore how non-homothetic preferences might affect the results. To that end, let utility be given by the familar Stone-Geary form

$$u_n^j = \left[\left(c_n^{j,a} - \bar{a}\right)^{\varepsilon}\left(c_n^{j,m}\right)^{1-\varepsilon}\right]^{\alpha} s_{u_n}^{j\,1-\alpha}, \tag{29}$$

where $\bar{a}$ is a minimum subsistence food intake requirement. As in Tombe (2015), it is useful to use data on household food budget shares $b_n^j \equiv P_n^a c_n^{j,a}/v_n^j$ to define final demand

$$D_n^j = \begin{cases} b_n^j v_n^j L_n^j & \text{if} \quad j = a \\ \alpha\left(1-\varepsilon\right)\left(\frac{1-b_n^j}{1-\alpha\varepsilon}\right) v_n^j L_n^j & \text{if} \quad j = m \\ \left(1-\alpha\right)\left(\frac{1-b_n^j}{1-\alpha\varepsilon}\right) v_n^j L_n^j & \text{if} \quad j = s \end{cases} \tag{30}$$

This is useful to define how demand and spending patterns respond in our counterfactuals without actually calibrating the subsistence parameter $\bar{a}$ or food price levels. Given budget shares b_n^j from data, counterfactual subsistence spending is $P_n^{ag\,\prime}\bar{a} = \left(\frac{b_n^j - \alpha\varepsilon}{1-\alpha\varepsilon}\right) v_n^j \hat{P}_n^a$ and therefore

$$D_n^{j\,\prime} = \begin{cases} \left(\left(\frac{b_n^j-\alpha\varepsilon}{1-\alpha\varepsilon}\right)\hat{P}_n^a + \alpha\varepsilon\left(\hat{v}_n^j\hat{L}_n^j - \left(\frac{b_n^j-\alpha\varepsilon}{1-\alpha\varepsilon}\right)\hat{P}_n^a\right)\right) v_n^j L_n^j & \text{if} \quad j = a \\ \alpha\left(1-\varepsilon\right)\left(\hat{v}_n^j\hat{L}_n^j - \left(\frac{b_n^j-\alpha\varepsilon}{1-\alpha\varepsilon}\right)\hat{P}_n^a\right) v_n^j L_n^j & \text{if} \quad j = m \\ \left(1-\alpha\right)\left(\hat{v}_n^j\hat{L}_n^j - \left(\frac{b_n^j-\alpha\varepsilon}{1-\alpha\varepsilon}\right)\hat{P}_n^a\right) v_n^j L_n^j & \text{if} \quad j = s \end{cases} \tag{31}$$

With these, spending is simply

$$X_i^j = D_n^j + \sum_k \sigma^{kj} R_i^k. \tag{32}$$

Another important change to the model governs how land prices change. Spending on land is $\eta^j R_n^j + s_n^{land} v_n^j L_n^j$ and labour income is $\beta^j R_n^j$ So nominal income is $(\eta^j + \beta^j)R_n^j + s_n^{land} v_n^j L_n^j$. Equilibruim price of land is

$$r_n^j S_n^j = \eta^j R_n^j + s_n^{land} v_n^j L_n^j$$

and since $v_n^j L_n^j = (\eta^j + \beta^j)R_n^j + s_n^{land} v_n^j L_n^j = \frac{(\beta^j+\eta^j)R_n^j}{1-s_n^{land}}$ we have

$$r_n^j S_n^j = \left[\eta^j + \frac{s_n^{land}}{1-s_n^{land}}(\beta^j + \eta^j)\right] R_n^j,$$

which simplifies to something similar to our earlier equation

$$r_n^j S_n^j = \left[\frac{s_n^{land}\beta^j + \eta^j}{(1-s_n^{land})\beta^j}\right] w_n^j L_n^j.$$

Thus,

$$\hat{r}_n^j = \frac{\left[\frac{s_n^{land\,\prime}\beta^j+\eta^j}{(1-s_n^{land\,\prime})}\right]}{\left[\frac{s_n^{land}\beta^j+\eta^j}{(1-s_n^{land})}\right]}\hat{w}_n^j\hat{L}_n^j$$

The initial land share is $(1-\alpha)\left(\frac{1-b_n^j}{1-\alpha\varepsilon}\right)$ and the new land share is $(1-\alpha)\left(1-\left(\frac{b_n^j-\alpha\varepsilon}{1-\alpha\varepsilon}\right)\frac{\hat{P}_n^a}{\hat{v}_n^j\hat{L}_n^j}\right)$. Real GDP changes are as before, but with nominal incomes deflated by $\hat{P}_n^j = \left(\hat{P}_n^{ag}\right)^{s_n^{ag}}\left(\hat{P}_n^{na}\right)^{s_n^{na}}\left(\hat{r}_n^j\right)^{s_n^{land}}$.

Finally, we solve for welfare changes and migration decisions. Optimal consumption demand by households are $P_n^a c_n^{j,a} = \bar{a}P_n^a + \alpha\varepsilon\left(v_n^j - \bar{a}P_n^a\right)$ for agriculture, $P_n^m c_n^{j,m} = \alpha(1-\varepsilon)\left(v_n^j - \bar{a}P_n^a\right)$ for manufactured goods, and finally $r_n^j s_{u_n}^j = (1-\alpha)\left(v_n^j - \bar{a}P_n^a\right)$ for housing. All together, indirect utility is

$$u_n^j \propto \frac{v_n^j - \bar{a}P_n^a}{\left(P_n^{j,a}\right)^{\alpha\varepsilon}\left(P_n^{j,m}\right)^{\alpha(1-\varepsilon)}\left(r_n^j\right)^{1-\alpha}}.$$

Given $P_n^a c_n^{j,a} = b_n^j v_n^j$, the indirect utility becomes

$$u_n^j \propto \left(\frac{v_n^j}{\left(P_n^a\right)^{\alpha\varepsilon}\left(P_n^m\right)^{\alpha(1-\varepsilon)}\left(r_n^j\right)^{1-\alpha}}\right)\left(\frac{1-b_n^j}{1-\alpha\varepsilon}\right).$$

As with Cobb-Douglas preferences, real incomes matter for welfare, but are adjusted in the non-homothetic preference case by excess non-food spending. Counterfactual food spending shares are $b_n^{j\,\prime} = \left(b_n^j - \alpha\varepsilon\right)\hat{P}_n^a/\hat{v}_n^j + \alpha\varepsilon$ and therefore welfare changes are

$$\hat{u}_n^j = \underbrace{\hat{\rho}\hat{w}_n^j\hat{P}_n^{-1}}_{\text{Real Wages}} \cdot \underbrace{\hat{\Gamma}_n}_{\text{Subsistence}} \tag{33}$$

where $\hat{P}_n = \left(\hat{P}_n^a\right)^{\alpha\varepsilon}\left(\hat{P}_n^m\right)^{\alpha(1-\varepsilon)}\left(\hat{r}_n^j\right)^{1-\alpha}$ and $\hat{\Gamma}_n^j \equiv \frac{1-b_n^{j\,\prime}}{1-b_n^j} = \frac{1-\alpha\varepsilon}{1-b_n^j}\left(1-\left(\frac{b_n^j-\alpha\varepsilon}{1-\alpha\varepsilon}\right)\frac{\hat{P}_n^a}{\hat{v}_n^j}\right)$. Non-homothetic preferences means welfare changes and real income changes are different, and this effect is captured by the change in non-food spending shares $\hat{\Gamma}_n^j$. With these welfare expressions in hand, worker migration decisions now result in

$$m_{ni}^{jk} = \frac{\left(u_i^k/\mu_{ni}^{jk}\right)^{\kappa}}{\sum_{m,s}\left(u_m^s/\mu_{nm}^{js}\right)^{\kappa}}.$$

With this alternative specification, we repeat the main counterfactual experiments of the paper. We use data on food spending share from China's yearly Provincial Macro-economy Statistics through the University of Michigan's *China Data Online*. The data distinguishes between rural and urban areas, which allows us to pin down b_n^j for each province and region. We provide all results in the third panel of Table 15, which are not qualitatively different from the results in the second panel. In fact, the results are slightly strong in the sense that internal trade and migration costs have a larger effect on GDP, and migration flows (and therefore movements out of agriculture) are also larger.

Heterogeneous Worker Productivity

Maintain the equal-proportional rebates to all workers from the previous two sub-sections, but now consider a final alternative model of worker heterogeneity. In our baseline model, differences in migration incentives were due to heterogeneous preferences. Now, consider workers with different levels of human capital across space and sectors. Formally, workers are endowed with a vector z_n^k of productivity for each of the $N \times 2$ region-sectors – these are i.i.d. across workers, regions, and sectors. Workers then choose where to live to maximize their real income net of migration costs $\mu_{ni}^{jk} z_i^k V_i^k$. The parameter z_i^k is distributed i.i.d. Frechet across all regions and sectors. This corresponds to an earlier version of our working paper.

The changes to the model are fairly straightforward, and involve introducing the notion of effective labour supply in addition to employment. Specifically, the total supply of effective labour in region n sector j is

$$H_n^j = \sum_{k \in \{ag,na\}} \sum_{i=1}^{N} \mu_{in}^{kj} \left(m_{in}^{kj} \right)^{-1/\kappa} m_{in}^{kj} \bar{L}_i^k., \tag{34}$$

where $h_{in}^{kj} = \mu_{in}^{kj} \left(m_{in}^{kj} \right)^{-1/\kappa}$ is the average productivity of workers from region i and sector k that work in region n and sector j, and therefore $H_n^j = \sum_k \sum_i h_{in}^{kj} m_{in}^{kj} \bar{L}_i^k$. With this in mind, all per-worker variables in the model are simply re-interpreted as per-effective-worker. All other aspects of the model remain unchanged, but with effective labour replacing employment where appropriate and with key model variables interpreted in per-effective worker terms. For instance, V_n^j would be real income per effective worker in region n and sector j.

In this framework, we can calibrate κ using observable wage data instead of an empirical estimates of the income-elasticity of migration. Given the Frechet distribution of productivity, the proof of Proposition 2 provides a means of estimating κ from individual earnings data. Namely, after migration ex-post earnings across individuals are distributed Frechet. The log of a Frechet distribution is Gumbel, with a standard deviation proportional to κ^{-1}. Specifically, log real incomes are distributed Gumbel with CDF

$$G(x) = e^{-\left[\sum_k \sum_{i=1}^{N} \left(\mu_{ni}^{jk} V_i^k \right)^{\kappa} \right] e^{-\kappa x}},$$

which has a standard deviation $\pi/(\kappa\sqrt{6})$. Importantly, the standard deviation of real earnings is independent of μ_{ni}^{jk} and V_i^k.

How do we estimate this standard deviation from data? In the data, we observe nominal earnings, which corresponds to $\mu_{ni}^{jk} z_i^k v_i^k$. The above expression, however, applies to *real* earnings. Fortunately, the difference between the two is identical for all sector k workers in region i and therefore $var(log(z_i^k V_i^k)) = var(log(z_i^k v_i^k))$. Next, μ_{ni}^{jk} is common to all (n, j)-registered workers now in sector k of region i; therefore, $var(log(\mu_{ni}^{jk} z_i^k V_i^k)) = var(log(\mu_{ni}^{jk} z_i^k v_i^k))$ across those work-

Table 16: Results with Worker Productivity Differences

Measured Change for	p.p. Change in Share of Internal Trade	External Trade	Ag. Emp.	Migrant Stock Within Province	Between Province	Per-Capita Income Variation	Aggregate Outcomes Real GDP	Welfare
With Baseline $\kappa = 1.50$								
Internal Trade	9.2	-0.7	-0.1	1.3%	-1.4%	-7.3%	9.5%	10.6%
External Trade	-0.7	3.9	-0.6	2.4%	3.1%	5.0%	4.2%	2.1%
All Trade	8.3	2.9	-0.6	3.5%	1.5%	-2.0%	13.8%	12.6%
Migration	0.3	-0.1	-1.6	11.3%	57.4%	-14.5%	8.3%	1.2%
Internal Changes	9.5	-0.8	-1.6	12.0%	55.7%	-19.5%	18.8%	12.1%
Everything	8.5	2.7	-2.2	13.9%	60.5%	-16.5%	23.4%	14.1%
Matching Observable Moments in the Earnings Distribution, for $\kappa = 2.54$								
Internal Trade	9.3	-0.7	0.0	1.6%	-2.3%	-7.1%	9.4%	10.9%
External Trade	-0.6	3.9	-0.7	2.8%	3.6%	5.8%	4.8%	2.5%
All Trade	8.3	2.9	-0.7	4.2%	1.1%	-1.1%	14.2%	13.3%
Migration	0.3	-0.1	-1.5	10.6%	63.3%	-0.9%	10.4%	2.0%
Internal Changes	9.5	-0.8	-1.4	11.6%	59.9%	-6.6%	20.7%	13.3%
Everything	8.6	2.8	-2.2	14.0%	66.2%	-3.5%	26.2%	15.6%

Notes: Displays aggregate response to various cost changes when worker heterogeneity is over productivity rather than spatial preferences. Marginal effects reflect the changes relative to the equilibrium with only productivity change. The migrant stock is the number of workers living outside their province of registration. Regional income variation is the variance of log real incomes *per capita* across provinces.

ers. We therefore identify the value of κ from the within-group nominal earnings variation, with groups defined by region-sector of registration and current region-sector of employment. From the 2005 Population Survey, we find an average within-group standard deviation of log earnings of 0.50, so $\kappa = 2.54$. Individual income data is not reported in the 2000 Census.

We report the main results in Table 16, and find our results are qualitatively robust to this alternative framework although one notable difference is worth pointing out. The real GDP effect of migration is larger, and larger than the gains in welfare. This is unsurprising, as migrant workers are now, on average, higher productivity. Their gains are also not mainly in terms of higher utility as in the baseline model, but higher real incomes. The extent to which observed aggregate real GDP growth in China accounted for by lower migration costs will therefore be larger in this formulation than our baseline model in the main paper.

Unbalanced Trade

Over the period we study, China's trade surplus was quite large – roughly 3% of GDP. The quantitative analysis in the paper, and many of the derivations, depended on trade balancing, not just between China and world, but for each of China's provinces. This was an innocuous assumption. Importantly, our estimates of trade and migration costs are unaffected by unbalanced trade. But to see if our other main quantitative results are affected, we augment the model here to incorporate exogenous trade surpluses and deficits, at the province level, in a fairly standard way.

The change to the model are fairly minor. Let S_n^j denote province n and sector j's trade surplus. Total income is then $v_n^j L_n^j = \frac{1}{\alpha}\left(\frac{\eta^j+\beta^j}{\beta^j} w_n^j L_n^j - S_n^j\right)$. That is, a trade surplus is a capital outflow, which shrinks a region's nominal income below its total sales. Another change to the model is how land rents change. Instead of $\hat{r}_n^j = \hat{w}_n^j \hat{L}_n^j$, as in the main model, we now have $\hat{r}_n^j = \omega_n^j \hat{w}_n^j \hat{L}_n^j + 1 - \omega_n^j$, where $\omega_n^j = \left(\frac{\beta^j(1-\alpha)+\eta^j}{\alpha} w_n^j L_n^j\right) / \left(\frac{\beta^j(1-\alpha)+\eta^j}{\alpha} w_n^j L_n^j - S_n^j \frac{1-\alpha}{\alpha}\right)$. All other model expressions remain unchanged.

Table 17: Results with Province-Level Trade Imbalances

Measured Change for	p.p. Change in Share of Internal Trade	External Trade	Ag. Emp.	Migrant Stock Within Province	Between Province	Per-Capita Income Variation	Aggregate Outcomes Real GDP	Welfare
Internal Trade	9.3	-0.8	0.0	0.8%	-1.9%	-6.1%	10.0%	10.6%
External Trade	-0.7	4.0	-0.5	1.9%	2.3%	1.9%	3.4%	2.7%
All Trade	8.2	3.0	-0.5	2.6%	0.4%	0.6%	14.0%	13.2%
Migration	0.1	0.1	-3.0	14.6%	82.4%	-14.5%	4.3%	8.5%
Internal Changes	9.3	-0.7	-2.9	15.2%	79.3%	-19.6%	14.8%	20.1%
Everything	8.3	3.1	-3.5	17.1%	84.1%	-15.9%	19.0%	22.7%

Notes: Displays aggregate response to various cost changes when trade does not balance at the province level. The model is augmented to incorporate exogenous and fixed imbalances that correspond to our data in the initial equilibrium.

Our data on trade flows allow us to estimate S_n^j only imperfectly for each province and region. We have province-level trade imbalances, and simply presume the trade surplus as a share of GDP is the same for both rural and urban regions within a province. Overall, rich provinces have surplus – in Shanghai, for example, the surplus is over 6% of GDP – and poor provinces have deficits. For the country as a whole, the trade surplus is 3% of GDP. With this data, we set S_n^j to match these surplus-to-GDP ratios in the initial equilibrium to match the data. We then infer the imbalance for the rest of the world such that $\sum_{n=1}^{N+1} S_n^j = 0$.

With these adjustments, we repeat our main quantitative experiments and display the results in Table 17. We see the falling migration and trade costs are similar to our main results in the paper. Importantly, the aggregate real GDP and welfare changes are only modestly different. We conclude our results are robust to the presence of unbalanced trade.

Alternative Parameter Values

We also report our main results for a variety of alternative values of the income-elasticity of migration κ. This is one of the more important parameters in our model, and we demonstrate here our main results are not overly sensitive to alternative values of it. We report in Table 18 the main results of the baseline model and for values of κ ranging from 1 to 3. In general, the smaller the value of this parameter, the larger are the gains from migration and the larger is the change in the number of migrants to the measured change in migration costs. This is clear across panels in Table 18, and largely to the measure of migration cost estimates are decreasing in κ for given values of real income and migration shares (see Section 4.1). The same is true for the inferred changes in migration costs. But, offsetting this, is that the welfare gains described in Theorem 2 show that for any given change in migration, aggregate gains are smaller for smaller κ. Our baseilne aggregate results from changes in migration costs are conservative, relative to the implied results for alternative values for κ.

Finally, we repeat these robustness exercises for alternative values of the trade-cost elasticity parameter θ. In Table 19 we report our main results for θ ranging from 3 to 8, which encompases the bulk of estimates found in the literature. More recent estimates, using a variety of methods, have converged to values around 4, which motivates it as for our main results. As with the migra-

Table 18: Results Under Alternative Value for κ

Measured Change for	Trade/GDP Ratio (p.p. Change) Internal	External	Migrant Stock Within Province	Between Province	Real GDP	Aggregate Welfare
Baseline Model: Main Results, $\kappa = 1.5$						
Internal Trade	9.2	-0.7	0.8%	-2.0%	10.7%	10.7%
External Trade	-0.7	3.9	1.8%	2.4%	3.8%	2.6%
All Trade	8.2	2.9	2.5%	0.3%	14.4%	13.2%
Migration	0.1	0.2	14.5%	82.4%	4.8%	8.5%
Internal Changes	9.2	-0.6	15.1%	79.3%	15.9%	20.3%
Everything	8.2	3.0	17.0%	84.1%	20.0%	22.8%
For $\kappa = 1$						
Internal Trade	9.2	-0.7	0.6%	-1.4%	10.7%	10.6%
External Trade	-0.7	3.9	1.4%	1.8%	3.7%	2.7%
All Trade	8.2	2.9	2.0%	0.4%	14.3%	13.2%
Migration	0.2	0.2	15.6%	92.4%	5.6%	10.5%
Internal Changes	9.2	-0.5	16.0%	90.0%	16.9%	22.5%
Everything	8.2	3.0	17.6%	94.1%	20.8%	25.1%
For $\kappa = 2$						
Internal Trade	9.2	-0.7	1.0%	-2.5%	10.6%	10.7%
External Trade	-0.7	3.9	2.2%	2.8%	3.9%	2.6%
All Trade	8.2	2.9	3.0%	0.1%	14.5%	13.2%
Migration	0.1	0.1	14.0%	75.2%	4.3%	8.5%
Internal Changes	9.2	-0.6	14.8%	71.6%	15.2%	20.1%
Everything	8.2	3.0	16.8%	76.8%	19.4%	22.7%
For $\kappa = 3$						
Internal Trade	9.2	-0.7	1.2%	-3.2%	10.6%	10.6%
External Trade	-0.7	3.9	2.6%	3.4%	4.1%	2.6%
All Trade	8.3	2.9	3.6%	-0.1%	14.6%	13.1%
Migration	0.0	0.1	13.8%	66.0%	3.5%	9.9%
Internal Changes	9.2	-0.6	14.8%	61.6%	14.2%	21.5%
Everything	8.2	3.0	17.0%	67.1%	18.6%	24.1%

Notes: Displays the main counterfactual experiments under various alternative specifications.

Table 19: Results Under Alternative Value for θ

Measured Change for	Trade/GDP Ratio (p.p. Change) Internal	External	Migrant Stock Within Province	Between Province	Real GDP	Aggregate Welfare
Baseline Model: Main Results, $\theta = 4$						
Internal Trade	9.2	-0.7	0.8%	-2.0%	10.7%	10.7%
External Trade	-0.7	3.9	1.8%	2.4%	3.8%	2.6%
All Trade	8.2	2.9	2.5%	0.3%	14.4%	13.2%
Migration	0.1	0.2	14.5%	82.4%	4.8%	8.5%
Internal Changes	9.2	-0.6	15.1%	79.3%	15.9%	20.3%
Everything	8.2	3.0	17.0%	84.1%	20.0%	22.8%
For $\theta = 3$						
Internal Trade	6.6	-0.6	0.6%	-1.8%	9.7%	9.8%
External Trade	-0.5	2.7	1.3%	1.9%	3.3%	2.5%
All Trade	6.0	1.9	1.8%	0.0%	13.0%	12.2%
Migration	0.1	0.1	14.6%	81.2%	4.7%	8.5%
Internal Changes	6.7	-0.5	15.0%	78.6%	14.8%	19.2%
Everything	6.0	2.1	16.2%	82.6%	18.4%	21.7%
For $\theta = 6$						
Internal Trade	14.9	-1.0	1.3%	-2.2%	12.7%	12.7%
External Trade	-1.1	6.9	3.1%	3.3%	5.0%	3.2%
All Trade	12.9	5.1	4.2%	1.1%	17.5%	15.5%
Migration	0.1	0.2	14.6%	84.0%	5.0%	8.5%
Internal Changes	14.8	-0.8	15.5%	80.1%	18.2%	22.5%
Everything	12.8	5.3	18.8%	86.9%	23.5%	25.2%
For $\theta = 8$						
Internal Trade	21.4	-1.3	1.7%	-2.3%	15.0%	14.9%
External Trade	-1.8	11.2	4.4%	4.3%	6.8%	4.3%
All Trade	17.7	8.1	6.0%	2.2%	21.2%	18.2%
Migration	0.1	0.2	14.7%	85.0%	5.2%	8.5%
Internal Changes	21.1	-1.1	16.0%	80.6%	20.7%	24.9%
Everything	17.4	8.2	21.0%	89.5%	27.6%	28.0%

Notes: Displays the main counterfactual experiments under various alternative specifications.

tion elasticity, there are two offsetting effects of changing this parameter. First, a larger θ implies smaller trade costs are inferred from a set of trade share observations. After all, a higher cost elasticity means lower costs are required to match observed trade shares relative to the frictionless counterfactual. But second, a larger θ means the welfare gains from any given change in trade shares will be larger. The latter effect tends to dominate, and our main results are therefore on the conservative side of possible results within a reasonable range for the parameter θ. Aggregate welfare gains from internal trade cost reductions, for example, range between 9.8% and 14.9%. Our baseline results are 10.7%.