Trade, Migration and Productivity: A Quantitative Analysis of China

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Abstract

We study how goods- and labor-market frictions affect aggregate labor 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 36% of the aggregate labor productivity growth between 2000 and 2005. Reductions in internal trade and migration costs are more important than reductions in external trade costs. Despite the decline, migration costs are still high and potential gains from further reform are large.

JEL Classification: F1, F4, R1, O4

Keywords: *Migration; internal trade; spatial misallocation; gains from trade; China*

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1 Introduction

China's recent growth has been nothing short of remarkable. From 2000 to 2007 – after joining the WTO and before the financial crisis – China's real GDP per capita nearly doubled. China's rapid ascent as a key player in the world economy is well known, but equally dramatic has been the growth of its internal economic integration. Trade between its provinces has increased more than trade between China and the rest of the world, and the flow of workers across regions within China represents the largest migration in human history. Policy changes may be an important cause of these developments. In the early 2000s, China 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 growth in aggregate productivity (Zhu, 2012). What role did the policy changes play in China's rapid growth? In this paper, we use a rich quantitative framework and uniquely detailed data to answer this question. We find that the internal trade and migration cost reductions, and the associated increases in trade and migration within China, account for 28% of China's aggregate labor productivity growth between 2000 and 2005. The reduction in international trade costs, on the other hand, accounted for only 8% of the growth. These results highlight the importance of internal reforms for China's growth and are in stark contrast to the widely held perception that China's growth during the period was an "export-led" experience.

Our quantitative framework builds on recent developments in international trade research. We develop a two-sector multi-region general equilibrium model featuring internal trade, international trade, and worker migration. Following Ahlfeldt et al. (2015) and Redding (2016), 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 and heterogeneous worker preferences regarding locations and sectors. We also incorporate into the model collective ownership of land, an important institutional feature of China that makes migration difficult. Even with these rich and realistic features, the model is still analytically tractable and can be easily used for quantitative analysis.

To facilitate our quantitative analysis, we compile a rich set of data on China's internal and external trade, internal migration, and spatial distribution of income. Using the data and our quantitative model we estimate both the levels of and changes in trade and migration costs in China. We find that trade costs were large in 2002, but they declined significantly between 2002 and 2007. On average, internal costs fell by 10-15% and international costs fell by almost 10% in non-agriculture and nearly 25% in agriculture. For migration costs, we consider them ongoing *flow* costs rather than *sunk* costs due to a unique institutional feature of China, the *hukou* (household registration) system that imposes large costs on working and living outside one's *hukou* location, 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*. According to our estimates for 2000, the average cost of moving from rural to urban areas within a province is equivalent to shrinking one's real income by a factor of nearly 3; between-province moves are an order of magnitude more costly. In addition, since all rural land and some urban land are collectively owned and there is a lack of rental market for land, migrants who leave their *hukou* location lose benefits from land. High migration costs and restrictive land markets mean only a small proportion of workers move; those who do move tend to be young workers facing lower migration costs. Between 2000 and 2005, however, migration costs did decline substantially – by 18% on average, and by almost 40% for between-province moves.

In a series of quantitative exercises using our calibrated model, we evaluate how the measured cost changes affect trade flows, migration, aggregate labor productivity and welfare. We find that the reductions in trade costs can account for most of the increases in China's internal and external trade between 2002 and 2007. They have relatively small effects on migration, but large effects on aggregate labor productivity and welfare, both of which increase by more than 14%. Because most provinces in China trade more within China than abroad, the internal trade cost changes contribute more to the gains in aggregate labor productivity and welfare than the external trade cost changes. Similarly, the measured changes in migration costs have small effects on trade shares, but large effects on migration and aggregate labor productivity and welfare. In response to the migration cost reductions, the stock of within-province and between-province migrants increase by roughly 15% and 82%, respectively. Most of the increases are rural-to-urban. Largely due to the reallocation of labor from agriculture to non-agriculture, aggregate labor productivity increases by around 5%. Aggregate welfare increases even more, by 11%, due to the direct welfare effect of the reductions in migration costs.

Despite the recent decline in trade and migration costs, the scope for further cost reductions remains large in China. We find that 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 such that one-third of Chinese workers move beyond their province of registration (a level consistent with U.S. migration rates), with real GDP per worker increasing by nearly 13% and welfare by 46%. Finally, we quantify the effects of allowing for private land ownership and a fully functioning land rental market so migrants no longer give up the returns to land when they move. We find that the number of migrant workers would significantly increase and the resulting welfare gain would be nearly 12%.

Our paper contributes to two broad literatures. First, there is a growing literature linking international trade flows with the spatial distribution of labor and economic activity within countries, such as Cosar and Fajgelbaum (2012); Dix-Carneiro and Kovak (2014); Allen and Arkolakis (2014); Redding (2016) and Caliendo et al. (2015). There are notable papers exploring internal migration costs, such as Morten and Oliveira (2018) and Bryan and Morten (2018); internal trade costs, such as Ghani et al. (2016); and empirical investigations of trade's effect on internal migration, such as McCaig and Pavcnik (2018) for Vietnam or Aguayo-Tellez and Muendler (2010) and Hering and Paillacar (2016) 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 China's expansion of both trade and internal migration – perhaps the largest and fastest ever recorded. Second, the recent macro-development literature has emphasized differences in aggregate total factor productivity (TFP) as a key source of large cross-country income differences (Klenow and Rodriguez-Clare, 1997; Hall and Jones, 1999; Caselli, 2005) and misallocation of inputs as an important reason for low levels of aggregate TFP in poor countries (Banerjee and Duflo, 2005; Restuccia and Rogerson, 2008; Hsieh and Klenow, 2009; Bartelsman et al., 2013). We study specific sources of misallocation in an important developing economy, a valuable research area highlighted by Restuccia and Rogerson (2013). Brandt et al. (2013) use a general equilibrium model to quantify the aggregate productivity loss due to misallocation of labor and capital across space in China, but the sources of misallocation are not 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 labor mobility in China, but their analysis is at a more aggregate level and without detailed modeling of trade and migration across space. Caliendo et al. (2017b) investigate the impact of internal and external distortions in a world economy with input-output linkages and also find that the impacts of internal distortions are much larger than international distortions.

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

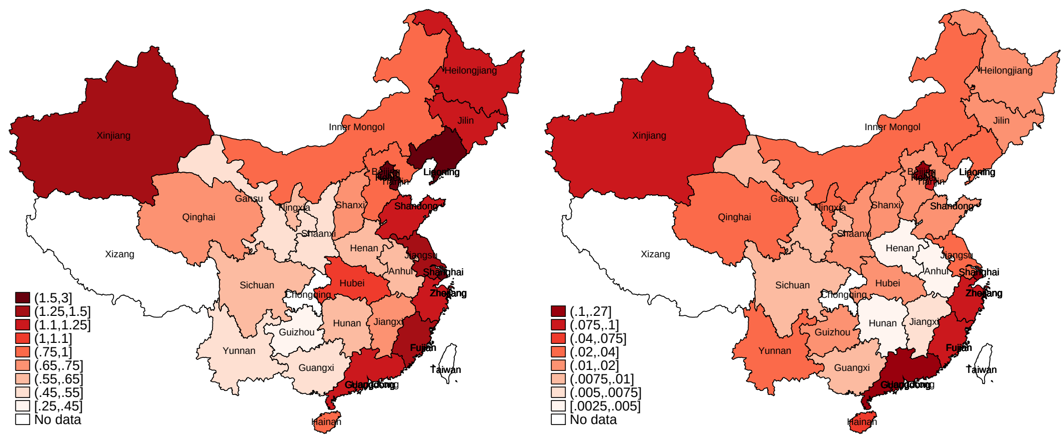
We first describe our data and highlight key facts about the Chinese economy. We then discuss migration and trade policies in place around 2000 and how they subsequently changed. Finally, we conduct some back-of-the-envelope calculations to illustrate the potential gains from these policy changes to motivate our more comprehensive quantitative analysis to come. There are 31 provinces in mainland China. We exclude Tibet in all that follows due to limited data and divide the other 30 provinces into agricultural and non-agricultural sectors.

2.1 Spatial Distribution of Income

Comparing real incomes across provinces and sectors is no trivial task. We need data on GDP, employment, and price levels for each 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

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

(a) Real GDP/Worker, Relative to Mean (b) Migrant Share of Total Employment



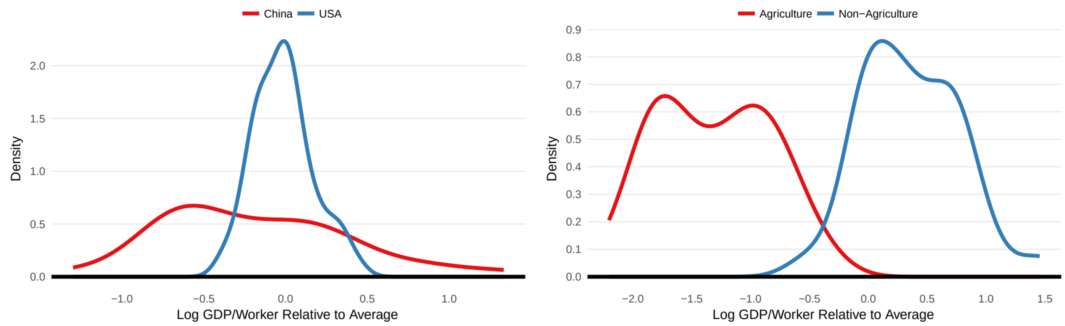
Note: Displays choropleths of relative real income levels for each of China's provinces and the migrant share of total employment. Dark reds indicate both high relative real incomes and large migrant shares of employment.

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 calculate 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, respectively.

With this data in hand, we find 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 2000. 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. In Figure 1a we plot the real GDP per worker for the 30 provinces in China in 2000. For comparison, we plot in Figure 2a the distribution of GDP per worker across US states along with the distribution across China's provinces. Since we do not have price level information for the US,

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.

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 controlling 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.

2.2 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 "non-agricultural (urban)" in a specific administrative unit that is at or lower than the county or 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 or 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 did not and risked arrest and deportation by the local authorities.

As the demand for migrant workers in manufacturing, construction, and labor 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 nation-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 their *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 for whom having access to public services is more important. Not surprisingly, there are more within-province than between-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).

We construct our own data on within- and between-province migration. The main sources of labor market data are the annual Rural Household Surveys and Urban Household Surveys conducted by the NBS. However, these residence-based surveys are known to underestimate migration. For studying migration, researchers have generally used the individual-level Population Census, as do we.[1] Specifically, we use the 1% sample of the 2000 Census and the 20% sample of the 2005 1%

[1]The new Longitudinal Survey on Rural Urban Migration in China (RUMiC) provides a more accurate picture of migration, but covers only nine provinces and fifteen cities. The survey results are largely consistent with the Population Census. Meng (2012) provides an overview of the labor market data in China and Chan (2013) discusses migration data.

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* 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.

Mini-Census as our data source for migration. Any worker in a province other than the province of their *hukou* is classified as an inter-provincial migrant. Any worker within their *hukou* province but in an occupation other than their *hukou* category (agricultural or non-agricultural) is classified as an intra-provincial migrant.

Table 1 presents the total number of inter-provincial and intra-provincial migrant workers for 2000 and 2005 and their shares of total employment. 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, and most of the increases are rural-to-urban migrants. 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 the migrant share of total provincial 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.

2.3 Trade Policies and Trade Patterns

China's international trade liberalization and WTO accession are well known; its internal trade liberalization is not. Several researchers have documented high internal trade costs in China in the 1990s (Young, 2000; Poncet, 2005). And others link local market protection to the size of a province's state sector (Bai et al., 2004). Since 2000, these trade barriers have fallen significantly. Some of the reduction was due to deliberate policy reforms, such as when the state council under then premier Zhu Rongji issued a 2001 directive prohibiting local governments from engaging in local market protections. More important, as a result of various SOE reforms, the size of the state sector has declined and therefore the local governments have less incentives to engage in local market protections. Improved transport infrastructure and logistics also helped lower internal trade costs.

To construct the trade data we use in our analysis, we turn to the inter-regional input-output tables for 2002 and 2007 constructed 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. 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.

From these data, Table 2 reports aggregate bilateral trade between eight regions in China 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, 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" π_{nn} – which is the fraction of spending allocated to local producers – along the diagonal.

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

Table 2: Internal and External Trade Shares of China

Importer	North-east	Beijing Tianjin	North Coast	Central Coast	South Coast	Central Region	North-west	South-west	Abroad	Total Other Prov.
	Exporter									
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 the appendix 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%.

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 was 0.88 compared to only 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 declining 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 exceptions. Their import shares from abroad declined during this period due to increases in imports from the rest of China. Overall, internal trade increased more than external 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]

2.4 Potential Gains from Migration and Trade

What have migration and trade cost reductions meant for China's economy? Before turning to our full general equilibrium model, we illustrate potential gains from increases in migration and trade flows with a back-of-the-envelope calculation based on a simple model. The calculation shows increases in migration and internal trade contributed more to aggregate GDP growth during the period than increases in international trade did. We will confirm this result with our full model to come.

Let y_n^j and l_n^j be the real GDP per worker and employment share in region n and sector j, and aggregate GDP per worker as $y = \sum_{n,j} y_n^j l_n^j$. 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, $g_x = \hat{x} - 1$ 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. Migration affects aggregate GDP through the change in employment shares $g_{l_n^j}$ – positively if workers migrate to relatively high GDP regions or sectors, and negatively otherwise. Trade affects aggregate GDP through its effect on $g_{y_n^j}$. Though more difficult to quantify than migration, Arkolakis et al. (2012) show that within a broad class of models aggregate gains from trade can be captured by changes in a region's home-share combined with an elasticity of trade parameter θ, which is typically estimated to be around 4. Specifically,

$$\hat{y}_n^j = \hat{A}_n^j \left(\hat{\pi}_{nn}^j \right)^{-1/\theta},$$

[2]Trade shares reported here are at the regional level only. For 2002, we compute trade shares for each province and sector and find, consistent with the regional data, interior provinces have higher home-shares than coastal provinces, and most provinces trade more within China than from abroad with the exception of the coastal provinces.

where A_n^j is region-n-sector-j's labor productivity under autarky. So, we have

$$g_{y_n^j} \approx g_{A_n^j} - \frac{1}{\theta}\frac{\triangle\pi_{nn}^j}{\pi_{nn}^j}.$$

We can further distinguish changes in home shares as due to changes in (1) spending allocated to other Chinese provinces, which we denote π_{nc}^j, and (2) spending allocated to international imports, which we denote π_{nw}^j. Since all shares must sum to one, we have $\triangle\pi_{nn}^j = -\triangle\pi_{nc}^j - \triangle\pi_{nw}^j$ and $g_{y_n^j} \approx \frac{1}{\theta}\left(\frac{\triangle\pi_{nc}^j}{\pi_{nn}^j} + \frac{\triangle\pi_{nw}^j}{\pi_{nn}^j}\right) + g_{A_n^j}$. Together with the earlier expression for $\hat{y}$, and our data on trade and migration,

$$g_y = \underbrace{\sum_{n,j}\omega_n^j\frac{1}{\theta}\frac{\triangle\pi_{nc}^j}{\pi_{nn}^j}}_{\substack{\text{Internal Trade}\\ 4.9\%}} + \underbrace{\sum_{n,j}\omega_n^j\frac{1}{\theta}\frac{\triangle\pi_{nw}^j}{\pi_{nn}^j}}_{\substack{\text{External Trade}\\ 0.5\%}} + \underbrace{\sum_{n,j}\omega_n^j g_{l_n^j}}_{\substack{\text{Migration}\\ 10.8\%}} + \underbrace{\sum_{n,j}\omega_n^j g_{A_n^j}}_{\substack{\text{Residual}\\ 40.9\%}}.$$

This simple expression decomposes aggregate growth into contributions from rising internal trade, international trade, migration and the residual (which is mainly productivity growth, but also includes the quantitatively small interaction term $g_{y_n^j}g_{l_n^j}$). We find migration contributes nearly 11% to China's aggregate labor productivity growth between 2000 and 2005, holding all other factors fixed. Increases in internal trade add 4.9% and international trade 0.5%. Migration matters because workers moved to the higher productivity regions and, more important, sector. The large productivity gap between agriculture and non-agriculture and the reallocation of labor 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 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.

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 take into account the equilibrium relationship between trade and migration: trade may induce changes in migration and migration may lead to changes in trade. Second, without a structural model we cannot quantify how much of the increases in trade and migration were due to the reductions in migration and trade costs. Third, we treated agriculture and non-agriculture symmetrically and ignored intermediate inputs and input-output linkages, which may have important effects on the magnitude of the gains from trade. Finally, we may have overestimated gains from migration by ignoring differences in fixed factor endowments (land) and regional comparative advantage. We turn next to a general 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 work by Eaton and Kortum (2002), Ahlfeldt et al. (2015) and Redding (2016). The model features two tradable sectors and multiple regions of China between which goods and labor 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 N provinces plus the world, indexed by $n \in \{1,...,N+1\}$. Each region has two sectors: agriculture and non-agriculture, denoted by $j \in \{ag, na\}$. Each region-sector is also endowed with a fixed factor (land, structures), denoted by $\bar{S}_n^j$, that is used for housing and production. Throughout the paper, we use a subscript ni to denote a flow (of spending or of workers) that goes from region n to region i. So the first subscript represent the origination region, and the second subscript the destination region. Similarly, we use a superscript jk to denote a flow that goes from sector j to sector k.

3.1 Worker Preferences

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 non-agricultural *hukou*. There are $\bar{L}_n^j$ workers with *hukou* in region n and sector j. Workers derive utility from final goods and residential housing. Let v_{in}^{kj} be the nominal income of a worker with *hukou* registration in region i and sector k, but works in region n and sector j. The worker maximizes the Cobb-Douglas utility[3]

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

subject to a budget constraint $P_n^{j,ag} C_n^{j,ag} + P_n^{j,na} C_n^{j,na} + r_n^j S_n^{j,h} \leq v_{in}^{kj}$, where $C_n^{j,ag}$ and $C_n^{j,na}$ are consumption of agricultural and non-agricultural goods with prices $P_n^{j,ag}$ and $P_n^{j,na}$, respectively, and $S_n^{j,h}$ housing structureas with a price r_n^j. The parameters $(\alpha, \psi^{ag}, \psi^{na})$ are preference weights such that $\alpha \in (0,1)$ and $\psi^{ag} = 1 - \psi^{na} \in (0,1)$, and ε_n^j is an idiosyncratic preference shifter that is i.i.d across workers, sectors and regions. Let L_{in}^{kj} be the number of such workers, and therefore $L_n^j = \sum_{k \in \{ag,na\}} \sum_{i=1}^N L_{in}^{kj}$ is the total number of workers working in region n and sector j, and $v_n^j = \sum_{k \in \{ag,na\}} \sum_{i=1}^N v_{in}^{kj} L_{in}^{kj} / L_n^j$ the average income there. Then, it is straightforward to show final demand for good j by workers in region n is

$$D_n^j = \alpha \psi^j \sum_{k \in \{ag,na\}} v_n^k L_n^k. \tag{2}$$

Similarly, final demand for housing there is $(1-\alpha) \sum_{k \in \{ag,na\}} v_n^k L_n^k$.

3.2 Production, Trade and Goods Prices

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

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

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 produc-

[3] The homothetic preferences greatly simplifies the analysis. In the Appendix, we expand the model to allow subsistence food requirements. All our main results hold.

ers of differentiated varieties. These varieties are produced by perfectly competitive firms using labor, intermediate inputs, and land with Cobb-Douglas technologies. The marginal cost of production for a firm with productivity φ is therefore

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

where β^j and η^j are labor 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 that sell to consumers in another incur a cost; those that sell within a region don't. Costs are iceberg and one must ship τ_{ni}^j units from region i for one unit to arrive in region n. Consumer prices are therefore $p_{ni}^j(\varphi)=\tau_{ni}^j c_n^j(\varphi)$. Facing these prices, buyers opt for the cheapest source. As in Eaton and Kortum (2002), we assume that φ is distributed Frechet with CDF $F_n^j(\varphi)=e^{-T_n^j\varphi^{-\theta}}$. Then equilibrium trade shares are

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

where π_{ni}^j is the fraction of region n spending allocated to sector j goods produced in region i (trade shares), and final goods prices are

$$P_n^j=\gamma\left[\sum_{i=1}^{N+1}T_i^j\left(\tau_{ni}^j c_i^j\right)^{-\theta}\right]^{-1/\theta}, \tag{5}$$

where γ is a constant, and the productivity parameter T_i^j.[4]

[4]The productivity parameter reflects both TFP and capital intensity. 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 here.

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

Land is not tradable and is 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 fixed factor income. Consumer preferences and production technologies are Cobb-Douglas, so 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 labor 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

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

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

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

as the effective fixed-factor "rebate rate" to workers, then we can write the incomes of workers registered in region n and sector j as $v_{ni}^{jk} = \delta_{ni}^{jk} w_i^k$. Note this differs from rebates proportional to wages (Redding, 2016) or lump-sum rebates (Caliendo et al., 2017a) found in the literature. Our assumption is motivated by the actual land ownership institution in China, which has an important negative effect on migration.

3.4 Internal Migration

Let m_{ni}^{jk} denote the share of workers registered in (n, j) who migrated to (i, k), where $\sum_k \sum_{i=1}^N m_{ni}^{jk} = 1$. These workers face migration costs. First, migrants forego land returns in their home region and rely only on labor income. Second, migrants incur a utility cost that lowers welfare by a factor μ_{ni}^{jk}. Finally, workers differ in their location preferences ε_n^j, which are i.i.d. across workers, regions, and sectors.

Given real wages $V_i^k \equiv w_i^k / \left(P_i^{ag\, \psi^{ag}} P_i^{na\, \psi^{na}} \right)^{\alpha} r_i^{k\, 1-\alpha}$ in all regions and sectors, workers from (n, j) choose (i, k) to maximize their welfare $\varepsilon_i^k \delta_{ni}^{jk} V_i^k / \mu_{ni}^{jk}$. The law of large numbers implies that the proportion of workers who migrate to region (i, k) is

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

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

Proposition 1 *Given real wages for each region and sector V_i^k, migration costs between all region-sector pairs μ_{ni}^{jk}, land rebates through δ_{ni}^{jk}, and a Frechet distribution $F_\varepsilon(x)$ of the heterogeneous preferences, the share of (n, j)-registered workers who migrate to (i, k) is*

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

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 modeled migration costs as affecting worker productivity, or allowed for heterogeneous productivity. We explore these possibilities in the appendix. Our main quantitative results are robust to these different modeling assumptions about migration.

3.5 Solving 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 changes in aggregate welfare and real GDP.

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

$$\hat{W} = \sum_{j} \sum_{n=1}^{N} \omega_n^j \hat{V}_n^j \hat{\delta}_{nn}^{jj} \left(\hat{m}_{nn}^j\right)^{-1/\kappa}, \tag{11}$$

where $\omega_n^j \propto \bar{L}_n^j V_n^j \delta_{nn}^{jj} \left(\hat{m}_{nn}^j\right)^{-1/\kappa}$ *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 for relative changes eases the calibration by eliminating many fixed components of the model. We must calibrate parameters $(\alpha, \psi^k, \beta^j, \eta^j, \sigma^{jk}, \theta, \kappa)$ and initial values $(\pi_{ni}^j, m_{ni}^{jk}, \bar{L}_i^j, V_i^j)$ only. And our quantitative analysis requires only changes in trade and migration costs, not levels, so our results are robust to any bias in estimated trade and migration cost levels that are constant over time.

Table 3: Calibrated Model Parameters and Initial Values

Parameter	Set To	Description
(β^{ag}, β^{na})	$(0.29, 0.22)$	Labor's share of output
(η^{ag}, η^{na})	$(0.28, 0.03)$	Land's share of output
$(\sigma^{ag,na}, \sigma^{na,ag})$	$(0.60, 0.06)$	Intermediate input shares
ψ^{ag}	0.095	Agriculture's share of final demand
α	0.87	Goods' expenditure share
θ	4	Elasticity of trade
κ	1.5	Elasticity of migration
π^j_{ni}	*Data*	Bilateral trade shares
m^j_{ni}	*Data*	Bilateral migration shares
$\bar{L}^j_n$	*Data*	Hukou registrations

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

3.6 Calibration

Besides the elasticities θ and κ, the model calibration is straightforward. We briefly discuss our approach here and leave a detailed discussion to the appendix. The calibration results are summarized in Table 3. Intermediate input shares σ^{jk} match our input-output data while the labor and land shares, β^j and η^j, also incorporate estimates from Adamopoulos et al. (2017). Agriculture's share of final demand $\psi^{ag} = 0.095$ is also from our input-output data, and implies $\psi^{na} = 0.905$. 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 that the housing share of expenditures is 13%. The total registrants by province and sector $(\bar{L}^j_n)$ and initial migration shares m^{jk}_{ni} are observable in China's 2000 Population Census. Total national employment for China is 636.5 million and we infer employment for the rest of the world $(\sum_j L^j_{N+1})$ at 2,103 million using the Penn World Table. Since we don't have trade data in 2000, we use trade shares generated from the 2002 China Regional Input-Output Tables to approximate the values of the trade shares π^j_{ni} in 2000. Finally, we use data on real GDP per worker by province and sector for V_n. In the model, trade balance ensures real GDP and real income per worker are equivalent. We explore unbalanced trade in the appendix.

3.6.1 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. For 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 non-agriculture. 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.

3.6.2 Income-Elasticity of Migration

We estimate the migration elasticity empirically. Equation 10 implies the share of workers from (n, j) that migrate to (i,k) is a function of real wage differences and migration costs. Specifically, $m_{ni}^{jk}/m_{nn}^{jj} = \left(V_i^k/\delta_{nn}^{jj}\mu_{ni}^{jk}V_n^j\right)^{\kappa}$. To estimate κ, we make two alternative assumptions about migration costs: (1) $\mu_{ni}^{jk} = \bar{\mu}_n^j d_{ni}^{\rho}\xi_{ni}^{jk}$, where d_{ni} is the distance between province n and i; or, more generally, (2) $\mu_{ni}^{jk} = \bar{\mu}_n^j \bar{\mu}_{ni}\xi_{ni}^{jk}$. Under these assumptions and given data on migration shares and real incomes, we estimate κ using the fixed effect regressions

$$\ln\left(\frac{m_{ni}^{jk}}{m_{nn}^{jj}}\right) = \kappa \ln\left(V_i^k\right) - \rho\kappa \ln d_{ni} + \gamma_n^j + \varsigma_{ni}^{jk}, \text{ for } (n,i) \neq (i,k) \tag{13}$$

or

$$\ln\left(\frac{m_{ni}^{jk}}{m_{nn}^{jj}}\right) = \kappa \ln\left(V_i^k\right) + \gamma_{ni} + \gamma_n^j + \varsigma_{ni}^{jk}, \text{ for } (n,i) \neq (i,k) \tag{14}$$

where $\gamma_n^j = -\kappa \ln \bar{\mu}_n^j - \kappa \ln\left(\delta_{nn}^{jj}V_n^j\right)$ is an origin province-sector fixed effect, $\gamma_{ni} = -\kappa \ln \bar{\mu}_{ni}$ is an origin-destination province-pair fixed effect, $\varsigma_{ni}^{jk} = -\kappa \ln \xi_{ni}^{jk} + \vartheta_{ni}^{jk}$, and ϑ_{ni}^{jk} is a measurement error term. Even after controlling for the fixed effects, destination income may still be influenced by other factors that are potentially related to migration costs – such as a province's institutional quality. We therefore consider multiple instruments for income. The identification assumption is that these instruments are uncorrelated with the residual migration costs ξ_{ni}^{jk} and the measurment errors ϑ_{ni}^{jk}.

First, we use the distance weighted average income of neighboring provinces. A region whose neighbors have high-income will tend to have high income, but the neighbor's income is plausibly exogenous to a given region's migration or income shocks. And second, we use a Bartik-style expected income instrument based on national average earnings by sector weighted by each province's distribution of employment across sectors. That is, $\tilde{v}_n^j = \sum_{k=1}^{K} \bar{w}^k l_n^k$ instruments for province-n's income using only its employment share l_n^k and national average earnings in subsector-k, within both agriculture and non-agriculture. To implement this, we use detailed data on individual earnings from the 2005 Population Census by detailed sector. We aggregate these to the broader agriculture and non-agriculture sectors for each province as the IV for V_i^k. In 2000, the Census does not provide the necessary income information but the China Urban Household Survey does (for a subset of provinces). We estimate equation 14 using two-stage least squares and report the results in Table 4. We also explore controlling for distance between n and i instead of province-pair fixed effects (at the cost of losing observations for within province, betwen sector migration), though the estimated κ is similar. In the table, regressions 5 and 6 use data from 2005 while the others use data from 2000.

Our estimates vary between 1.19 and 1.61, so we opt to set $\kappa = 1.5$ and explore a range of $\kappa \in [1,3]$ in the appendix. These estimates are in line with the literature. Fajgelbaum et al. (2018), for example, use variation in U.S. state taxes to estimate the elasticity of migration and a distance-weighted average of tax rates in other states to instrument for each state's own taxes. While their estimates vary across specifications, the closest to our setup corresponds to $\kappa = 1.39$. Bryan and Morten (2018) is also comparable, though their model features worker productivity draws that vary across locations. They estimate their Frechet migration parameters with a regression of earnings on migration (the reverse of equation 14) combined with information on the distribution of earnings across workers within an origin-destination paid. They instrument for migration shares m_{ni} using all other regions

Table 4: The Income-Elasticity of Migration in China

	OLS		IV					
			Neighboring Income		Expected Income 2005 Census Data		Expected Income 2000 UHS Data	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Destination Real Income V_i^k	1.32***	1.33***	1.40***	1.40***	1.20***	1.19***	1.61***	1.28***
	[0.02]	[0.02]	[0.03]	[0.02]	[0.03]	[0.02]	[0.08]	[0.03]
Distance	-1.50***		-1.51***		-1.39***		-1.51***	
	[0.04]		[0.04]		[0.04]		[0.06]	
origin-destination province-pair FEs	No	Yes	No	Yes	No	Yes	No	Yes
origin province-sector FEs	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Obs.	3480	3540	3480	3540	3480	3540	1972	2006
R^2	0.608	0.852	0.607	0.852	0.615	0.848	0.616	0.847
First-Stage: Dep. Var. is Income Gap								
Neighboring Income			1.02***	1.02***				
			[0.01]	[0.005]				
Expected Income (2005)					0.49***	0.48***		
					[0.004]	[0.002]		
Expected Income (2000)							2.30***	5.07***
							[0.013]	[0.005]
F-Stat			167	59	455	75	41	11

Note: Displays the results of various regressions to estimate the income-elasticity of migration. The first IV uses uses the distance-weighted average income of all other provinces. The second IV is a Bartik-style instrument of expected incomes using only variation in within-nonagricultural and within-agriculture composition of employment and national average earnings by sub-sector. For 2000, we use a subset of provinces for which the Urban Household Survey provides income data by sector.

$m_{(-n)i}$, similar to our first instrument but for migration shares. Their estimates for Indonesia would correspond to $\kappa = 2.7$ in our model. In the appendix, we explore a similar setup where workers differ in productivity rather than preferences. In that setting, κ maps directly into observable moments of the individual earnings distribution and we find $\kappa = 2.54$.

4 Inferring Migration and Trade Costs

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

4.1 Migration Costs

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

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

where δ_{nn}^{jj} is from Equation 9. We use the full set of migration cost changes between all province-sector pairs in the quantitative analysis to come. In Table 5 we summarize these costs, their changes between 2000 and 2005, and the initial migrant stocks in 2000. Migration costs μ_{ni}^{jk} in 2000 averages 2.8. The loss of land income from a worker's home region δ_{nn}^{jj} averages 1.9. Thus, the overall cost of migration $\delta_{nn}^{jj}\mu_{ni}^{jk}$ averages around 5.3. Migration costs are largest for those switching provinces. For agricultural to non-agricultural switches, costs average 25.2 for workers also migrating across provinces and only 2.2 for those remaining within their home province. In terms of changes, by 2005 migration costs declined to 82% of their level in 2000. Costs of switching provinces fell the most, from 25.2 to 15.4, and the cost of switching sectors within one's home province fell from 2.2 to 1.8.

While the estimated migration costs are large, they relate to factors that we think are important for migration and are broadly consistent with evidence from individual survey data. First, our estimated migration costs are strongly correlated with the distance between regions. When we regress log migration costs on log distance, controling for origin fixed effects, we find a distance-elasticity of 1. Second, 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 wages. Given $V_{n,c}^j$ and cohort-specific migration shares $m_{ni,c}^{jk}$, we estimate cohort-specific migration costs $\mu_{ni,c}^{jk}$ and find these increase with age. For migrants under age 24, their costs average around 1.5, which is significantly lower than the average cost across all age groups reported in Table 5. We report details of the distance regressions and age-cohort analysis in the appendix. Finally, the 2002 China Household Income Project surveys rural-urban migrants and asks 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 earn at home, suggesting substantial migration costs exist to maintain such a large gap.[5] These are costs for workers who *did* migrate; costs for those who did not could be much higher.

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 certain low income provinces then, holding migration costs constant, there would be less migration from these low income provinces to high income ones. Since our model has no amenity differences across provinces, the model implied migration costs may be too large. However, our quantitative analysis relies only on changes in migration costs, and therefore this potential bias migration cost levels will not affect our results as long as the systematic location differences did not change over the period we study.

What is behind the measured change in migration costs? First, the national administrative reform in 2003 that either streamlined the process or eliminated for migrants to get temporary residence permits is one important factor. Second, reforms to China's *hukou* system may also play a key role. Kinnan et al. (2017) examines these reforms in details and document major reforms to the *hukou* system that took

[5]Some of the gap may reflect selection based on individuals' comparative advantage, which cannot be controled given the data limitation of the survey.

Table 5: Migration Rates and Average Migration Costs

	Initial Share of Employment	Average Migration Costs μ_{in}^{kj} Level in 2000	Level in 2005	Relative Change
Overall	0.174	2.82	2.31	0.82
Agriculture to Non-agriculture Migration Cost Changes				
Overall	0.16	2.63	2.16	0.82
Within Prov.	0.13	2.21	1.83	0.83
Between Prov.	0.03	25.21	15.43	0.61
Between Provinces Migration Cost Changes				
Overall	0.04	24.75	15.08	0.61
Within Ag.	0.003	47.67	42.22	0.89
Within Nonag.	0.01	21.02	12.2	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 period weights to average the 2005 costs to capture only changes in costs and not migration patterns.

place in Beijing, Zhejiang, Shanghai, Jiangsu, and Shandong during the period of our analysis. These regions began allowing migrants to receive a local resident permit if they have an apartment, a stable job, and (in the case of Shanghai) a special skill. Consistent with their finding, we find our measure of migration costs fell more for migrants moving to these five provinces than for migrants moving to other provinces (22% vs 15%). Finally, there had been significant investment in highways during this period. Many rural counties were newly connected to highways, making it much easier for rural migrants to move. Indeed, we find that the farther apart are two provinces, the larger the reduction in our measured migration cost between them, implying that geographical distance contributed less to migration costs in 2005 than in 2000.

4.2 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

Table 6: Bilateral Trade Costs in 2002 and the Change to 2007

	Exporter								
Importer	North-east	Beijing Tianjin	North Coast	Central Coast	South Coast	Central Region	North-west	South-west	Abroad
Average Trade Cost Levels in 2002									
Northeast		2.61	2.89	3.65	2.71	3.32	2.57	3.36	3.43
Beijing/Tianjin	2.60		1.92	3.13	2.44	3.08	2.66	3.44	2.84
North Coast	2.79	1.87		2.69	2.51	2.58	2.53	3.61	3.30
Central Coast	3.80	3.27	2.89		2.21	2.27	2.70	3.34	2.43
South Coast	3.74	3.39	3.59	2.91		3.03	3.08	2.93	2.62
Central Region	3.18	2.94	2.53	2.15	2.06		2.46	3.12	4.08
Northwest	3.02	3.07	2.96	2.94	2.50	2.95		2.89	4.61
Southwest	3.10	3.20	3.47	2.95	1.96	3.08	2.38		4.25
Abroad	4.94	4.10	4.75	3.37	2.63	6.05	5.79	6.32	
Average Trade Cost Changes from 2002 to 2007									
Northeast		0.91	0.90	0.84	0.83	0.88	0.92	0.88	0.81
Beijing/Tianjin	0.84		0.89	0.91	0.89	0.80	0.75	0.85	0.78
North Coast	0.87	0.93		1.00	0.87	0.78	0.72	0.77	0.80
Central Coast	0.76	0.88	0.92		0.88	0.82	0.74	0.85	0.81
South Coast	0.77	0.93	0.87	0.92		0.81	0.72	0.80	0.92
Central Region	0.88	0.91	0.85	0.96	0.90		0.78	0.84	0.75
Northwest	0.99	0.92	0.85	0.96	0.88	0.86		0.87	0.68
Southwest	0.89	0.94	0.83	0.97	0.85	0.82	0.78		0.74
Abroad	0.88	0.93	0.92	0.98	1.05	0.77	0.64	0.79	

Note: Displays the aggregate average trade costs in 2002 and the relative changes from 2002 to 2007. We aggregate the sectoral trade costs using expenditure weights, but use the sector specific estimates in the quantitative analysis.

the trade-cost elasticity θ. Specifically,

$$\bar{\tau}_{ni}^{j} \equiv \sqrt{\tau_{ni}^{j}\tau_{in}^{j}} = \left(\frac{\pi_{nn}^{j}\pi_{ii}^{j}}{\pi_{ni}^{j}\pi_{in}^{j}}\right)^{1/2\theta}, \qquad (15)$$

which is a direct result of equation 4, but can be generalized 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 15 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. We report average trade cost levels in 2002 and relative changes to 2007 in Table 6, and sector and year specific estimates in the appendix. Some notable patterns emerge. Both internal and external trade costs are largely decreasing. The trade-weighted relative change within China is $\bar{\hat{\tau}}_{ni}^{ag} = 0.87$ and $\bar{\hat{\tau}}_{ni}^{na} = 0.89$. For trade between China and the world, the average changes are $\bar{\hat{\tau}}_{ni}^{ag} = 0.77$ and $\bar{\hat{\tau}}_{ni}^{na} = 0.92$.

5 Quantitative Analysis

Our quantitative analysis explores the effect of measured changes in trade and migration costs starting from an initial equilibrium that fits the data in 2000. Before presenting the specific results, we summarize our main findings here. Overall, our full analysis is consistent with the back-of-the-envelope calculation in Section 2. Both methods show that, between 2000 and 2005, internal trade and internal migration contributed more to China's GDP growth and welfare than international trade. We do, however, discover some important new insights from the full model. First, increases in trade and migration were mainly due to the reductions in trade costs and migration costs, respectively, and the interaction effects between the two types of cost changes are small. Second, the gains from trade cost reductions are larger than the back-of-the envelope calculation because intermediate inputs in productions magnify those gains. Finally, the gain from migration cost reductions is smaller than the back-of-the-envelope calculation because land as a fixed factor and regional comparative advantage imply diminishing returns to migration.

5.1 Lower Migration Costs

From the initial equilibrium in 2000, we solve the changes in equilibrium outcomes by using the estimated changes in migration costs $\hat{\mu}_{in}^{kj}$ from section 4.1, and hold

Table 7: Effects of Various Migration Cost Changes

	Trade Shares (p.p. Change)		Migrant Stock			
	Internal	External	Within Province	Between Province	Real GDP per worker	Aggregate Welfare
All	0.1	0.1	14.5%	80.8%	4.8%	11.1%
No Land Inputs	0.1	0.2	14.4%	85.6%	5.3%	8.4%
& No Housing	0.1	0.2	13.8%	90.4%	6.5%	7.6%
& $\theta \to \infty$	-0.2	0.1	23.2%	119.2%	11.8%	6.2%
Agriculture to Non-agriculture Migration Cost Changes						
Overall	0.1	0.1	15.2%	52.9%	4.3%	9.1%
Within Provinces	-0.0	-0.1	22.8%	-9.7%	2.0%	5.9%
Between Provinces	0.1	0.2	-7.0%	69.9%	2.8%	3.5%
Between Provinces Migration Cost Changes						
Overall	0.2	0.3	-7.8%	97.9%	3.2%	5.5%
Within Agriculture	-0.0	0.0	-0.1%	2.3%	-0.0%	0.1%
Within Nonagriculture	0.1	0.1	-1.0%	30.9%	0.7%	2.2%

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 change in internal and external trade shares are the expenditure weighted average changes in region's $\sum_{n \neq i} \pi_{ni}^{j}$ and π_{nN}^{j}. The migrant stock is the number of workers living outside their province of registration.

trade costs and productivity parameters fixed ($\hat{\tau}_{ni}^{j} = \hat{T}_{n}^{j} = 1$ for all n and i). We report the results in Table 7.

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 81% – from just over 4% to 7.5% of the labor force. This is equivalent to an increase of over 21 million migrant workers, most of them are rural-to-urban migrants. Within provinces, there are also substantial moves from agriculture to non-agriculture. The stock of non-agricultural workers with agricultural *hukou* within the same province increases by nearly 15%, from over 13% of the labor force to over 15.2%–nearly an increase of 12 million migrant workers. The national share of labor in agriculture declines by 3 percentage points. The large reallocation of labor benefits China as a whole: real GDP per worker and welfare rise 4.8% and 11.1%, respectively. The larger increase in the welfare is due to the direct effects of lower migration costs that directly increase the welfare of migrants.

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. 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 just over 0.1 percentage points on average (and provincial home shares π_{nn}^{j} decline by nearly 0.3 percentage points), 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 increase aggregate labor productivity by 2% and welfare by 5.9%. Lower costs of migration between sectors and provinces increase labor productivity by 2.8% and welfare by 3.5%. Overall, the aggregate productivity and welfare gains from the reductions in costs to rural-urban migration, both within- and between-provinces, are 4.3% and 9.1%, respectively. They are much larger than the gains from the changes in the costs of within-sector, between-province migration, which are negligible for agriculture and 0.7% and 2.2%, respectively, for non-agriculture.

The 4.8% aggregate labor productivity gain from the reductions in migration costs is smaller in magnitude than the 10.8% gain we get from the back-of-the-envelope calculation. The gain is lower because of two diminishing return forces in our quantiative model that were ignored in the bank-of-the envelope calculation: land as a fixed factor and regional comparative advantage. When we assume there is no land input in production, the model implied aggregate labor produtivity gain increases from 4.8% to 5.3%. If we assume that there is no demand for housing, the gain increases to 6.5%. Finally, if we assume no land input, no housing and the goods produced in different regions are perfect substitutes ($\theta \to \infty$), so that there is no regional comparative advantage, the aggregate labor productivity gain from migration cost reductions is 11.8%, close to the back-of-the-envelope estimate.

Table 8: Effects of Trade Cost Changes

	Trade Shares (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%	-1.8%	11.2%	11.3%
External Trade	-0.7	3.9	1.8%	2.4%	4.0%	2.9%
All Trade	8.2	2.8	2.5%	0.5%	15.2%	14.1%
No Change in Migration						
Internal Trade	9.2	-0.8	-	-	11.2%	11.2%
External Trade	-0.6	3.7	-	-	3.4%	3.4%
All Trade	8.3	2.7	-	-	14.5%	14.5%
No Intermediate Inputs						
Internal Trade	8.6	-0.5	0.3%	-1.4%	3.0%	3.3%
External Trade	-0.7	3.9	1.5%	1.6%	1.1%	0.3%
All Trade	7.6	3.2	1.6%	0.1%	4.1%	3.5%
No Intermediate Inputs and No Change in Migration						
Internal Trade	8.8	-0.5	-	-	3.1%	3.1%
External Trade	-0.7	3.8	-	-	0.7%	0.7%
All Trade	7.8	3.1	-	-	3.7%	3.7%

Notes: Displays aggregate response to various trade cost changes. All use trade cost changes as measured, though set $\hat{\tau}_{ni}^{j} = 1$ 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 $\sum_{n \neq i} \pi_{ni}^{j}$ and π_{nN}^{j}. The migrant stock is the number of workers living outside their province of registration.

5.2 The Effect of Lower Trade Costs

We now 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). The top panel of Table 8 displays the model implied changes in trade shares, migrant stocks, aggregate labor productivity and welfare. Changes in trade shares are expenditure weighted average changes across all provinces and sectors. With lower internal trade costs, the share of expenditures allocated to producers in other provinces within China increases by an average of over 9 percentage points while the share allocated to international producers falls by less than 1 percentage point. Lower external trade costs reveal the opposite pattern. Home shares fall in both cases, but by a much larger amount from 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 inter-provincial migrants declines by -1.8% (equivalent to approximately 0.5 million workers). Intuitively, reductions in internal trade costs disproportionately lower goods prices in poor, interior regions. The resulting increase in real income means that fewer workers are willing to migrate than before. On the other hand, the stock of workers who switch sectors within their home province increased by 0.8%. Overall, the impact of internal trade cost reductions on migration is small. The impact of international trade cost reduction is slightly larger. Richer coastal regions disproportionately benefit from lower international trade costs, so 2.4% more workers relocate there in addition to 1.8% more workers switching sectors within their home province.

In response to lower internal trade costs, aggregate labor productivity and welfare both dramatically increase by over 11%. In contrast, external trade cost reductions result in much smaller increases in aggregate labor productivity and welfare, 4% and 2.9%, respectively. The differential impacts are not due to any significant differences in the magnitude of cost reductions. To illustrate this, we simulate $\hat{\tau}_{ni}^{j} = 0.9$ for both internal and external trade costs separately; aggregate welfare increases by 7.8% from internal trade cost reductions, but only 2.2% from external trade cost reductions. Instead, differences in the initial volume of trade is the cause. The direct effect of a trade cost reduction on welfare is that a smaller portion of traded goods will be lost (melted) due to the iceberg trade cost. And since most provinces in China allocate a larger share of their spending to goods from other provinces than to goods from abroad, the direct effect of trade cost reductions is larger for internal trade than for external trade. There are maybe other general equilibrium effects of trade cost reductions on trade shares and migration, but they are second order relative to the direct effect.[6]

The magnitude of the gains from the trade cost reductions we report here are larger than the gains in Section 2's back-of-the envelope calculation. We investigate the sources of the difference by simulating a special case of our model with no intermediate input and no change in migrant stocks. The results are reported in the bottom panel of Table 8. In this case, the reductions in the internal and external trade costs result in similar changes in trade shares as in the benchmark case. However, their impact on the growth rates of the aggregate GDP per worker are much smaller,

[6] Allen et al. (2014) and Fan et al. (2014) show in trade models like ours (but without migration), the first order effect of any bilateral trade cost change on welfare is the change in the iceberg trade cost times the share of expenditures allocated to the trade between the two partners.

3.1% and 0.7%, which are closer to the growth rates of 4.9% and 0.5% we get from the bank-of-the envelope calculation. We further investigate the roles played by endogenous migration and intermediate input in generating the larger gains from trade in our full model. The results are reported in the second and third panel of Table 8, respectively. When we shut down the endogenous migration responses to the trade cost reductions, by keeping the worker allocation across sectors and regions the same as that of the initial equilibrium in 2000, the model generates similar changes in trade shares and aggregate GDP growth rates as in the benchmark case. Endogenous migration is therefore not the reason for the larger gains, which is not surprising given the small migraion responses to trade costs changes we reported earlier. But when we allow for endogenous migration responses but assume no intermediate input in the production of tradable varieties, the model generates similar changes in trade shares as in the benchmark case but much lower aggregate GDP growth rates. Thus, the larger gains from trade cost reductions in our full model is mainly due to the importance of intermediate inputs in production.[7]

5.3 Decomposing China's Recent Economic Growth

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 resulting 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 calibrated changes in the productivity parameters, our model matches growth data by construction, 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

[7]For more on intermediates and the gains from trade, see Costinot and Rodriguez-Clare (2014).

Table 9: Decomposing China's Aggregate Labor Productivity Growth

	Marginal Effects		
	Real GDP per Worker Growth	Share of Growth	Standard Deviation
Overall (All Changes)	57.1%	–	–
Productivity Changes	36.9%	0.64	1.3%
Internal Trade Cost Changes	10.2%	0.18	0.3%
External Trade Cost Changes	4.5%	0.08	0.7%
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	3.2%	0.06	0.9%
Within-Province, Ag-Nonag	1.5%	0.03	0.3%

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 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. Shares may not sum to one due to rounding. The growth rates are continuously compounded rates.

in which each component is introduced matters in evaluating the marginal contribution of one particular component.[8] In Table 9 we report the average marginal contribution to aggregate growth of each component across all permutations.

Reductions in trade and migration frictions account for more than one-third of China's overall growth. Reductions in internal trade and migration costs contributes roughly 28% (15.8% out of the 57.1%). In stark contrast, international trade cost reductions account for only 8% of the overall growth (4.5% 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 growth in the last column of Table 9. This reflects the extent to which the order of changes matters. Relative to the average, the variability of each component's marginal contribution across permutations is small.

[8]In the appendix, we illustrate this by comparing the effects of migration and trade costs changes with and without changes in the productivity parameters.

Table 10: Potential Gains from Further Trade and Migration Liberalization

	Relative to 2005 Eq'm	
	Change in Real GDP	Aggregate Welfare
Average Internal Trade Costs as in Canada	12.5%	16.3%
A One-Third Inter-Provincial Migrant Share	12.8%	45.6%
Both Together	26.0%	69.2%

Notes: Reports the change in real GDP and welfare that result from changing China's internal trade and migration costs such that average trade costs correspond to estimates for Canada, and 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.

6 Potential Gains from Further Reform

Another advantage of the quantitative model is that we can use it to evaluate the potential gains from further reform, to which we turn now.

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 labor 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 non-agricultural 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 10. We find China's real GDP and welfare could increase by a further 12.5% and 16.3% 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 the potential gains to China from lowering migration costs sufficiently to achieve this same one-third share of inter-provincial migrants. We find $\hat{\mu}_{ni}^{jk} = 0.22$ 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 12.5% and 12.8%, respectively. The result suggests that there is scope for further migration reform in China and large potential gains from doing so.

6.2 Land Reform

As current land ownership institution an important friction inhibiting labor mobility, we explore the effects of an alternative land ownership regime. All our prior analysis involved changing measured trade and migration costs, but land ownership remained with non-migrant local workers. Now, we explore the effect of allowing a worker to retain land ownership rights regardless of residency

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

$$\delta_{ni}^{jk} = 1 + \frac{(1-\alpha) v_n^j L_n^j + \frac{\eta^j}{\beta^j} w_n^j L_n^j}{w_i^k \bar{L}_n^j}. \tag{16}$$

Holding migration costs fixed,

$$\frac{\hat{m}_{ni}^{jk}}{\hat{m}_{nn}^{jj}} = \left(\frac{\hat{\delta}_{ni}^{jk} \hat{V}_i^k}{\hat{\delta}_{nn}^{jj} \hat{V}_n^j} \right)^{\kappa}, \tag{17}$$

Table 11: Effect of Individual Ownership Land Reform

	% Change
Welfare	11.8%
Real GDP	-2.4%
Migration, Within-Province	96.3%
Migration, Between-Province	38.0%

	Share of Population	
	Initial Equilibrium	New Equilibrium
Agricultural Workers	52.9%	56.6%
Stock of Migrants, Urban-Rural	2.1%	10.9%
Stock of Migrants, Rural-Urban	14.0%	19.1%

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.

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 and therefore low land rents 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 11 and describe the full algorithm in Appendix B.

Moving to individual land ownership increases both welfare and the number of migrants but decreases real GDP. As suggested by our earlier derivations, migration is disproportionately 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 11%, while rural to urban migration increases from 14% to 19.1%. The resulting increase in agricultural workers in the relatively low real-GDP regions accounts for drop in the aggregate GDP. Overall, the stock of within-province migrants nearly doubles and the stock of between-province migrants increases by 38%. As a result, welfare rises by nearly 12% as more workers are able to live where they prefer, and may take their higher land rebates from urban areas to live in lower cost rural areas.

7 Conclusion

China experienced rapid growth between 2000 and 2005. Many attribute this to the rapid external trade liberalization associated with China's accession to WTO in 2001, and the resulting export expansion supported by 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 reductions in internal trade and migration costs account for 28% of China's aggregate labor productivity growth between 2000 and 2005, while external trade costs reductions account for only 8%. Despite the reductions, internal trade and migration costs in China are still high and the gains from further liberalization are large – especially with respect to land reform.

While our results may lead one to conclude international liberalization matters little for aggregate outcomes, the contribution of trade liberalization that we quantify is the effect of trade-induced resource reallocation only. 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 did not study, such as FDI and the associated technology transfers (as in Ramondo and Rodriguez-Clare, 2013) and the influence of external trade liberalization on internal policy reforms. We leave 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 non-agriculture'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 non-agricultural hukou) currently working in province i and employed in sector k (agricultural or non-agricultural). 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 Interregional 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 non-agriculture. 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 eight 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 each factors' share of value-added $\tilde{\beta}/(\tilde{\beta}+\tilde{\eta}+\tilde{\alpha})$, $\tilde{\eta}/(\tilde{\beta}+\tilde{\eta}+\tilde{\alpha})$, and $\tilde{\alpha}/(\tilde{\beta}+\tilde{\eta}+\tilde{\alpha})$.

Let's start with $\tilde{\alpha}$. In our data, returns to land are attributed to labour in the agricultural sector but to operating surpluses in non-agricultural sectors. Thus, non-labour's share of output in agriculture is capital's share in the data while we have to net out land's share from the non-agricultural sector. To do this, we assume land's share of value-added is 0.06, as in Caselli and Coleman (2001), which is subtracted from the 0.17 non-labour share of non-agricultural output in our data. Thus, we find $\tilde{\alpha}^{ag} = 0.06$ and $\tilde{\alpha}^{na} = 0.15$.

Next, consider $\tilde{\beta}$ and $\tilde{\eta}$. In our data, value-added's shares of gross output is 0.59 in agriculture and 0.35 in non-agriculture. As mentioned, labour and land value-added are both within agricultural labour compensation in our data. In recent work, Adamopoulos et al. (2017) estimate labour's share of value-added in China's agricultural sector as 0.46. Combined with our data, this implies land's share of value-added is 0.44. Thus, together with our estimates for capital's share of gross output, we have $\beta^{ag} = 0.46 \times 0.59/(1-0.06) = 0.29$ and $\eta^{ag} = 0.44 \times 0.59/(1-0.06) = 0.28$. In non-agriculture,we have $\beta^{na} = 0.53 \times 0.35/(1-0.15) = 0.22$ and $\eta^{na} = 0.06 \times 0.35/(1-0.15) = 0.03$.

Finally, input-output shares are directly from our input-output data. Overall, non-agricultural inputs are 0.25 of agricultural gross output and 0.61 of non-agricultural gross output. Further, agricultural inputs are 0.16 of agricultural gross output and 0.04 of non-agriculture. 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 non-agriculture respectively, and the second row are the input shares for non-agriculture.

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 12: 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*

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

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 $\bar{V}_n^j = V_n^j \delta_{nn}^{jj} \left(m_{nn}^{jj}\right)^{-1/\kappa}$. 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 $W = \sum_n \sum_j \lambda_n^j V_n^j \delta_{nn}^{jj} \left(m_{nn}^{jj}\right)^{-1/\kappa}$. Taking the ratio of counterfactual W' to initial W yields

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

where $\omega_n^j = \left(\lambda_n^j V_n^j \delta_{nn}^{jj} \left(m_{nn}^{jj}\right)^{-1/\kappa}\right) / W$, 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

$$\hat{c}_{ni}^{j} = \hat{w}_{i}^{j\,\beta^{j}} \hat{r}_{i}^{j\,\eta^{j}} \left(\prod_{k \in \{ag,na\}} \hat{P}_{i}^{k\,\sigma^{jk}} \right), \tag{18}$$

$$\hat{\pi}_{ni}^{j} = \frac{\hat{T}_{i}^{j} \left(\hat{\tau}_{ni}^{j} \hat{c}_{i}^{j} \right)^{-\theta}}{\sum_{m=1}^{N+1} \pi_{nm}^{j} \hat{T}_{m}^{j} \left(\hat{\tau}_{nm}^{j} \hat{c}_{m}^{j} \right)^{-\theta}}, \tag{19}$$

$$\hat{P}_{n}^{j} = \left[\sum_{m=1}^{N+1} \pi_{nm}^{j} \hat{T}_{m}^{j} \left(\hat{\tau}_{nm}^{j} \hat{c}_{m}^{j} \right)^{-\theta} \right]^{-1/\theta}. \tag{20}$$

Given $\pi_{ni}^{j\,\prime} = \hat{\pi}_{ni}^{j} \pi_{ni}^{j}$, equations 2, 6 and 7 solve counterfactual expenditures $X_{ni}^{j\,\prime}$, revenues $R_{ni}^{j\,\prime}$, and incomes $\sum_{j} v_{n}^{j\,\prime} L_{n}^{j\,\prime}$. We therefore know $\hat{w}_{n}^{j} = \hat{R}_{n}^{j} / \hat{L}_{n}^{j}$ and $\hat{r}_{n}^{j} = \hat{R}_{n}^{j}$. All together, these expressions give changes in prices $\hat{P}_{n}^{j}$, trade flows $\hat{\pi}_{ni}^{j}$, and wages $\hat{w}_{n}^{j}$ per effective worker as a function of changes in trade costs ($\hat{\tau}_{ni}^{j}$), underlying productivity ($\hat{T}_{n}^{j}$), and employment ($\hat{L}_{n}^{j}$). It remains to solve for changes in migration flows. As the change in real incomes is

$$\hat{V}_{n}^{j} = \frac{\hat{w}_{n}^{j\,\alpha}}{\left(\hat{P}_{n}^{ag\,\varepsilon} \hat{P}_{n}^{na\,1-\varepsilon} \right)^{\alpha} \hat{L}_{n}^{j\,1-\alpha}}, \tag{21}$$

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

$$\hat{m}_{ni}^{jk} = \frac{\left(\hat{\delta}_{ni}^{jk} \hat{V}_{i}^{k} / \hat{\mu}_{ni}^{jk} \right)^{\kappa}}{\sum_{k} \sum_{i'=1}^{N} m_{ni'}^{jk'} \left(\hat{\delta}_{ni'}^{jk'} \hat{V}_{i'}^{k'} / \hat{\mu}_{ni'}^{jk'} \right)^{\kappa}}. \tag{22}$$

These shares then imply $L_{n}^{j\,\prime} = \sum_{i,k} m_{in}^{kj\,\prime} \bar{L}_{i}^{k}$ and, from equation 9, $\hat{\delta}_{ni}^{jk}$.

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 $r_{n}^{j} S_{n}^{j} / \bar{L}_{n}^{j}$ 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 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

$$\delta_{ni}^{jk} = 1 + \frac{(1-\alpha) v_{n}^{j} L_{n}^{j} + \frac{\eta^{j}}{\beta^{j}} w_{n}^{j} L_{n}^{j}}{w_{i}^{k} \bar{L}_{n}^{j}}. \tag{23}$$

Migration costs are held constant, so

$$\frac{\hat{m}_{ni}^{jk}}{\hat{m}_{nn}^{jj}} = \left(\frac{\hat{\delta}_{ni}^{jk}\hat{V}_i^k}{\hat{\delta}_{nn}^{jj}\hat{V}_n^j}\right)^{\kappa}, \tag{24}$$

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

$$v_n^{j\prime}L_n^{j\prime} = w_n^{j\prime}L_n^{j\prime} + \sum_{i,k}\rho_i^{k\prime}m_{in}^{kj\prime}\bar{L}_i^{k\prime}. \tag{25}$$

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

$$w_n^{j\prime}L_n^{j\prime} = \beta^j \sum_{i=1}^{N+1}\pi_{ni}^{jk\prime}\left[\alpha\varepsilon^j\sum_k v_n^{k\prime}L_n^{k\prime} + \sum_k \frac{\sigma^{kj}}{\beta^k}w_n^{k\prime}L_n^{k\prime}\right]. \tag{26}$$

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 18 to 20, we then solve for counterfactual prices $\hat{P}_n^j$ and trade shares $\hat{\pi}_{ni}^{jk}$. Given the new trade shares, equations 25 and 26 solve $v_n^{j\prime}$ and $w_n^{j\prime}$. With these, the new prices for goods and housing, equations 23 and 24 imply new labor 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 15 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 non-agriculture. 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.

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.

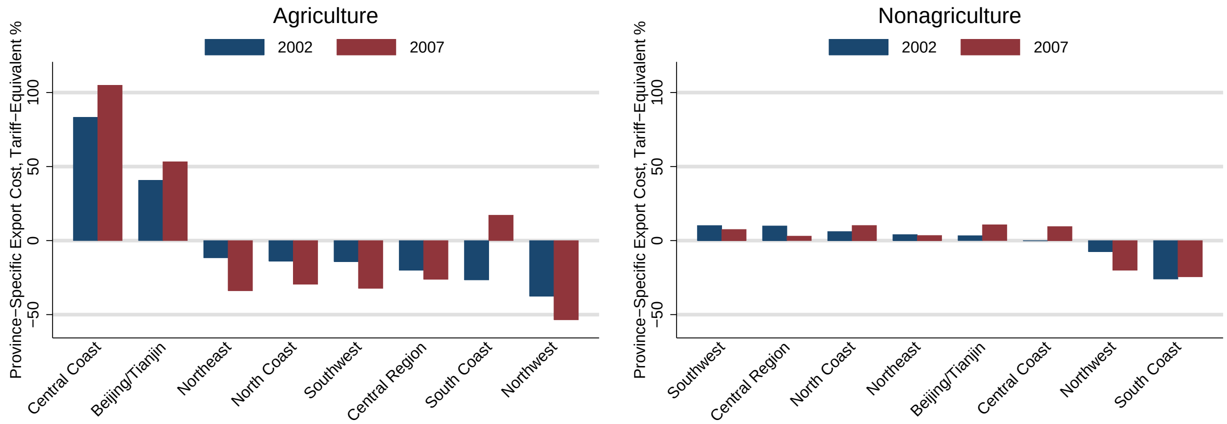
If trade costs have only a symmetric and exporter-specific component, and if the symmetric component is well proxied by geographic distance, then we can estimate t_i^j from

$$ln\left(\pi_{ni}^{j}/\pi_{nn}^{j}\right)=\delta^{j}ln\left(d_{ni}\right)+\iota_n^j+\eta_i^j+\varepsilon_{ni}^{j}, \tag{27}$$

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 non-agricultural 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. Combined with the Head-Reis Index estimates $\bar{\tau}_{ni}^{j}$, we estimate our preferred measure of trade costs and display their level in 2002 by sector and the relative changes between 2002 and 2007 is displayed in Tables 13 and 14.

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.

Table 13: 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 Non-agriculture, 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).

Though we use asymmetric trade costs in our main analysis, our results do not depend on it. To ensure our quantitative analysis is robust to only measuring trade costs, we re-estimate trade cost changes based only on $\bar{\tau}_{ni}^{j}$. We report these results in Table 15. Quantitatively, there are only minor changes.

Table 14: Relative Changes of Bilateral Trade Costs

	Exporter								
Importer	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 Non-agriculture, $\hat{\tau}_{ni}^{na}$									
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 for agriculture and nonagriculture for eight broad regions. In the simulation, we apply these changes to the provinces within each region.

Changes in Productivity Parameters

So far we have held the efficiency 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 resulting 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 $\hat{T}_n^j$ thus calibrated, the model precisely matches $\hat{V}_n^j$ and therefore also $\hat{m}_{ni}^{jk}$.

We display our main results in Table 16. The first row displays the effect of $\hat{T}_n^j$ alone. Aggregate labor productivity, welfare, and trade volumes all rise significantly, but trade shares change little. The stock of inter-provincial migrants increases significantly because some rich provinces like Shanghai have larger increase in productivity than other less rich provinces. Within-province between-sector migration increases slightly. We also display the marginal effects of trade and migration cost changes in the second panel of Table 16. The marginal effects of changing trade costs are similar to our earlier results, though there are some notable interaction effects. Internal migration cost changes, for example, contribute more to aggregate real GDP growth with the change in productivity parameters. Again, this is because faster productivity growth in rich regions such as Shanghai makes the gain from inter-provincial migration larger.

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

Table 15: Results With Only Symmetric Trade Costs

Measured Change for	Trade Shares (p.p. Change) Internal	External	Migrant Stock Within Province	Between Province	Real GDP	Aggregate Welfare
Baseline Model: Main Results						
Internal Trade	9.2	-0.7	0.8%	-1.8%	11.2%	11.4%
External Trade	-0.7	3.9	1.8%	2.4%	4.1%	2.9%
All Trade	8.2	2.8	2.5%	0.5%	15.2%	14.1%
Migration	0.1	0.1	14.5%	80.8%	4.8%	11.1%
Internal Changes	9.2	-0.6	15.1%	78.1%	16.4%	23.8%
Everything	8.3	3.0	16.9%	83.0%	20.8%	26.8%
With Only Symmetric Trade Costs $\bar{\tau}_{ni}^{j}$						
Internal Trade	9.0	-0.7	0.5%	-2.0%	10.9%	11.0%
External Trade	-0.6	3.5	0.7%	0.7%	3.4%	2.9%
All Trade	8.1	2.6	1.2%	-1.1%	14.4%	13.8%
Migration	0.1	0.1	14.5%	80.8%	4.8%	11.1%
Internal Changes	9.0	-0.5	14.9%	77.5%	16.1%	23.3%
Everything	8.1	2.7	15.6%	80.0%	19.8%	26.4%

Notes: Displays the main counterfactual experiments if all trade costs changes were based only on the Head-Reis Index for trade costs. These exclude all asymmetries estimated from the fixed effects regression decribed in the appendix.

our main results are not overly sensitive to alternative values of it. We report in Table 17 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 17, 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.

Finally, we repeat these robustness exercises for alternative values of the trade-cost elasticity parameter θ. In Table 18 we report our main results for θ ranging from 3 to 8, which encompass 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 migration 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.

Age-Specific Migration Costs in 2005

To explore the variation in migration costs across workers by age, we use China's 2005 Population Census. This data reports individual worker income, which we use to re-estimate μ_{ni}^{jk} by age cohort. We are unable to estimate migration cost changes, as the Census 2000 data does not

Table 16: Effects of Various Cost and Productivity Parameter Changes

Measured Change for	Trade Shares (p.p. Change) Internal	External	Migrant Stock Within Province	Between Province	Aggregate Outcomes GDP/Worker	Welfare
Efficiency, $\hat{T}_n^j$	-0.1	0.0	3.6%	28.0%	42.5%	35.9%
All Changes *	7.9	2.7	22.2%	131.3%	77.2%	74.7%
Marginal Effects (changes relative to what productivity delivers)						
Internal Trade	9.1	-0.7	0.8%	-3.7%	11.1%	11.5%
External Trade	-0.6	3.5	4.8%	5.6%	5.4%	1.8%
All Trade	8.2	2.5	5.5%	1.9%	16.5%	13.2%
Migration	0.0	0.2	12.4%	77.9%	6.6%	9.8%
Internal Changes	8.9	-0.5	13.1%	71.6%	18.1%	22.6%
Everything	8.0	2.7	17.9%	80.7%	24.3%	24.2%
No Change in Productivity (consistent with earlier tables)						
Internal Trade	9.2	-0.7	0.8%	-1.8%	11.2%	11.3%
External Trade	-0.7	3.9	1.8%	2.4%	4.1%	2.9%
All Trade	8.2	2.8	2.5%	0.5%	15.2%	14.1%
Migration	0.1	0.1	14.5%	80.8%	4.8%	11.1%
Internal Changes	9.2	-0.6	15.1%	78.1%	16.4%	23.8%
Everything	8.3	3.0	16.9%	83.0%	20.8%	26.8%

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.

include individual income. As in the text, we estimate

$$\mu_{ni,a}^{jk} = \frac{1}{\delta_{nn}^{jj}} \left(\frac{V_{i,a}^{k}}{V_{n,a}^{j}} \right) \left(\frac{m_{nn,a}^{jj}}{m_{ni,a}^{jk}} \right)^{1/\kappa} \qquad for\, n \neq i,$$

using age-cohort a migration shares $m_{ni,a}^{jk}$, and cohort-specific real income levels $v_{n,a}^{j}$. For the non-migrant land income adjustment δ_{nn}^{jj} we use a common value for all ages. To estimate real income levels in a manner consistent with aggregate real GDP per worker data by province and sector, we adjust the Census reported incomes $v_{n,a}^{j}$ as $V_{n,a}^{j} = V_{n}^{j} \cdot \left(\frac{v_{n,a}^{j}}{\sum_{a'} \omega_{n,a}^{j} v_{n,a}^{j}} \right)$, where V_{n}^{j} is province n and sector j's real GDP per worker, as in the text, and $\omega_{n,a}^{j} = \frac{l_{n,a}^{j}}{\sum_{a'} l_{n,a'}^{j}}$ is the share of that province and sector's employment accounted for by age cohort a. While the aggregate estimate of migration costs is $\mu_{ni}^{jk} = 2.3$ in 2005, we find this varies systematically across age groups. We display all estimates across age cohorts from 15 to 54 in Figure 4. We find migration costs range from a low of $\mu_{ni,a}^{jk} = 1.5$ for workers under the age of 24, to a high of nearly $\mu_{ni,a}^{jk} = 3$ for older workers.

Table 17: Results Under Alternative Migration Elasticities κ

Measured Change for	Trade Shares (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%	-1.8%	11.2%	11.4%
External Trade	-0.7	3.9	1.8%	2.4%	4.1%	2.9%
All Trade	8.2	2.8	2.5%	0.5%	15.2%	14.1%
Migration	0.1	0.1	14.5%	80.8%	4.8%	11.1%
Internal Changes	9.2	-0.6	15.1%	78.1%	16.4%	23.8%
Everything	8.3	3.0	16.9%	83.0%	20.8%	26.8%
For $\kappa = 1$						
Internal Trade	9.2	-0.7	0.6%	-1.3%	11.2%	11.2%
External Trade	-0.7	3.9	1.4%	1.9%	3.9%	2.8%
All Trade	8.2	2.8	2.0%	0.5%	15.1%	13.9%
Migration	0.2	0.2	15.5%	91.1%	5.6%	16.1%
Internal Changes	9.2	-0.6	16.0%	89.0%	17.4%	29.2%
Everything	8.3	3.0	17.5%	93.1%	21.6%	32.2%
For $\kappa = 2$						
Internal Trade	9.2	-0.7	0.9%	-2.3%	11.2%	11.4%
External Trade	-0.7	3.9	2.1%	2.9%	4.2%	3.0%
All Trade	8.2	2.8	2.9%	0.5%	15.3%	14.3%
Migration	0.1	0.1	14.0%	73.4%	4.2%	8.8%
Internal Changes	9.2	-0.6	14.7%	70.3%	15.7%	21.2%
Everything	8.3	3.0	16.7%	75.6%	20.2%	24.4%
For $\kappa = 3$						
Internal Trade	9.2	-0.7	1.2%	-2.9%	11.1%	11.5%
External Trade	-0.7	3.9	2.5%	3.6%	4.3%	3.1%
All Trade	8.3	2.8	3.5%	0.5%	15.4%	14.5%
Migration	0.0	0.1	13.7%	63.8%	3.4%	6.6%
Internal Changes	9.2	-0.6	14.6%	60.1%	14.7%	18.8%
Everything	8.2	2.9	16.8%	65.8%	19.3%	22.0%

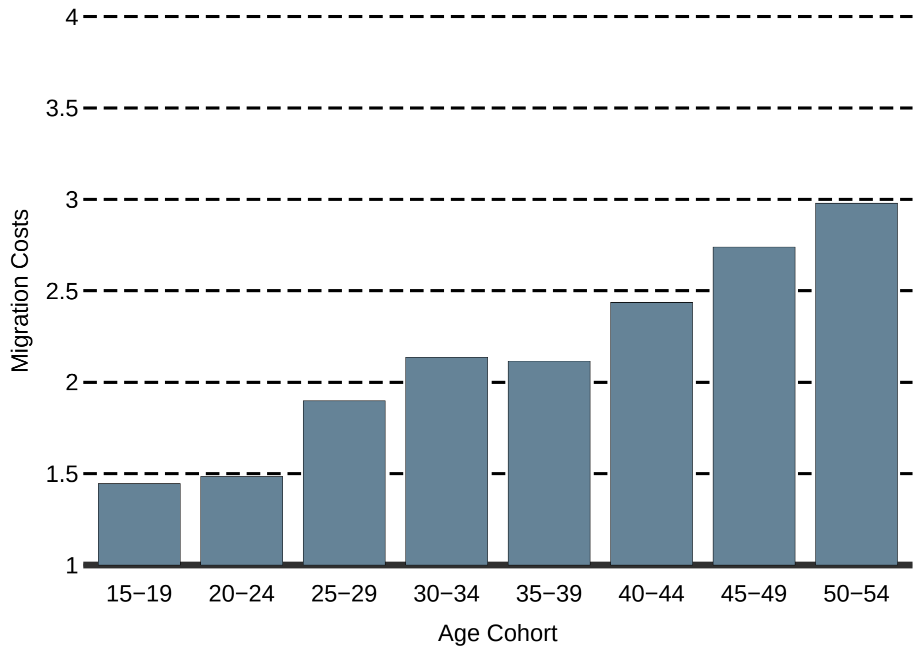
Notes: Displays the main counterfactual experiments under various migration elasticities.

Table 18: Results Under Alternative Trade Elasticities θ

Measured Change for	Trade Shares (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%	-1.8%	11.2%	11.4%
External Trade	-0.7	3.9	1.8%	2.4%	4.1%	2.9%
All Trade	8.2	2.8	2.5%	0.5%	15.2%	14.1%
Migration	0.1	0.1	14.5%	80.8%	4.8%	11.1%
Internal Changes	9.2	-0.6	15.1%	78.1%	16.4%	23.8%
Everything	8.3	3.0	16.9%	83.0%	20.8%	26.8%
For $\theta = 3$						
Internal Trade	6.6	-0.6	0.6%	-1.7%	10.2%	10.4%
External Trade	-0.5	2.7	1.3%	2.0%	3.6%	2.7%
All Trade	6.0	1.9	1.8%	0.2%	13.8%	13.0%
Migration	0.1	0.1	14.6%	79.7%	4.6%	11.0%
Internal Changes	6.7	-0.5	15.0%	77.3%	15.3%	22.6%
Everything	6.1	2.0	16.2%	81.4%	19.1%	25.6%
For $\theta = 6$						
Internal Trade	15.0	-1.0	1.2%	-2.0%	13.4%	13.5%
External Trade	-1.1	6.9	3.0%	3.4%	5.4%	3.6%
All Trade	13.0	5.1	4.1%	1.4%	18.5%	16.6%
Migration	0.1	0.2	14.5%	82.2%	4.9%	11.1%
Internal Changes	14.9	-0.8	15.4%	78.9%	18.8%	26.2%
Everything	12.9	5.2	18.7%	85.7%	24.6%	29.6%
For $\theta = 8$						
Internal Trade	21.5	-1.3	1.7%	-2.0%	15.8%	15.8%
External Trade	-1.8	11.2	4.3%	4.3%	7.3%	4.7%
All Trade	17.7	8.0	6.0%	2.6%	22.6%	19.6%
Migration	0.1	0.2	14.6%	83.2%	5.1%	11.2%
Internal Changes	21.2	-1.1	15.9%	79.5%	21.4%	28.8%
Everything	17.5	8.1	20.8%	88.2%	29.0%	32.8%

Notes: Displays the main counterfactual experiments under various alternative trade elasticities.

Figure 4: Migration Costs μ_{ni}^{jk}, by Age Cohort in 2005



Notes: Displays the average migration cost mu_{ni}^{jk} for migrants in 2005 by age cohort.

Migration Costs vs Geographic Distance

Migration costs between provinces are strongly related to geographic distance. To estimate bilateral distance, we construct the population weighted distance between provinces from the Gridded Population of the World data. The average distance is nearly 1,400 kilometers, ranging from a high of 122 to 3,730 kms. As in Section 3.6.2, we presume here that migration costs take the form $\mu_{ni}^{jk} = \bar{\mu}_n^j d_{ni}^{\rho} \xi_{ni}^{jk}$. We then estimate

$$ln\left(\mu_{ni}^{jk}\right) = \rho\, ln\left(d_{ni}\right) + \delta_n^j + \varepsilon_{ni}^{jk},$$

where δ_n^j is a source province-sector fixed effect, and ρ is the elasticity of migration costs with respect to distance. We find $\rho = 1.01$ in 2000 and $\rho = 0.94$ in 2005. The change in migration costs $\hat{\mu}_{ni}^{jk}$ is also related to distance. Using the same specification as above, but with migration changes as the dependent variable, we find $\rho = -0.07$. This implies that the further apart two provinces are, the greater the reduction in migration costs between 2000 and 2005. We report these results in Table 19. In addition, we incorporate information on new highway construction between the capital cities of each province pair. Specifically, we construct a dummy variable that equals one for a given province-pair if there exists a highway connecting their two capital cities in 2005 but not 2000, and zero otherwise. We find that while there is no statistically significant relationship between changes in migration costs and new highway construction. But, for distant province pairs, new highways matter. The mean value for $ln(d_{ni})$ is 7.1, so the coefficient on our interaction term implies that province pairs that are further apart than average and saw a new highway connection

Table 19: Migration Costs and Distance Regressions

	Migration Costs μ_{ni}^{jk}				
	Year 2000	Year 2005	Change in Migration Costs $\hat{\mu}_{ni}^{jk}$		
Log Bilateral Distance, $ln(d_{ni})$	1.01***	0.94***	-0.07***	-0.07***	0.03
	[0.03]	[0.03]	[0.02]	[0.02]	[0.03]
New Highway Built				0.01	1.67***
				[0.03]	[0.29]
Distance : New Highway					-0.24***
					[0.04]
origin province-sector FEs	Yes	Yes	Yes	Yes	Yes
Obs.	3480	3480	3480	3480	3480
R^2	0.573	0.615	0.227	0.227	0.235

Notes: Displays the relationship between distance, migration costs, and migration cost changes. The "New Highway Built" dummy identifies whether a new highway was completed between 2000 and 2005 connecting the capital cities of the two provinces.

built experienced a greater drop in migration costs than those that did not see a new highway connection built. The positive coefficient on new highways does not imply that migration costs increases between those provinces relative to others, just that their costs did not decrease as much.

Non-Homothetic 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 familiar Stone-Geary form

$$u_n^j = \left[\left(c_n^{j,a} - \bar{a} \right)^{\varepsilon} \left(c_n^{j,m} \right)^{1-\varepsilon} \right]^{\alpha} s_{u_n}^{j\,1-\alpha}, \tag{28}$$

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

$$D_n^j = \begin{cases} b_n^j v_n^j L_n^j & \text{if} \quad j = a \\ \alpha \left(1 - \varepsilon\right) \left(\frac{1 - b_n^j}{1 - \alpha\varepsilon} \right) v_n^j L_n^j & \text{if} \quad j = m \\ \left(1 - \alpha\right) \left(\frac{1 - b_n^j}{1 - \alpha\varepsilon} \right) v_n^j L_n^j & \text{if} \quad j = s \end{cases} \tag{29}$$

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

$$D_n^{j\,\prime}=\begin{cases}\left(\left(\frac{b_n^j-\alpha\varepsilon}{1-\alpha\varepsilon}\right)\hat{P}_n^a+\alpha\varepsilon\left(\hat{v}_n^j\hat{L}_n^j-\left(\frac{b_n^j-\alpha\varepsilon}{1-\alpha\varepsilon}\right)\hat{P}_n^a\right)\right)v_n^jL_n^j & \text{if} \quad j=a\\ \alpha\left(1-\varepsilon\right)\left(\hat{v}_n^j\hat{L}_n^j-\left(\frac{b_n^j-\alpha\varepsilon}{1-\alpha\varepsilon}\right)\hat{P}_n^a\right)v_n^jL_n^j & \text{if} \quad j=m\\ \left(1-\alpha\right)\left(\hat{v}_n^j\hat{L}_n^j-\left(\frac{b_n^j-\alpha\varepsilon}{1-\alpha\varepsilon}\right)\hat{P}_n^a\right)v_n^jL_n^j & \text{if} \quad j=s\end{cases} \tag{30}$$

With these, spending is simply

$$X_i^j=D_n^j+\sum_k\sigma^{kj}R_i^k. \tag{31}$$

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

$$r_n^jS_n^j=\eta^jR_n^j+s_n^{land}v_n^jL_n^j$$

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

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

which simplifies to something similar to our earlier equation

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

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 $P_n^ac_n^{j,a}=\bar{a}P_n^a+\alpha\varepsilon\left(v_n^j-\bar{a}P_n^a\right)$ for agriculture, $P_n^mc_n^{j,m}=\alpha(1-\varepsilon)\left(v_n^j-\bar{a}P_n^a\right)$ for manufactured goods, and finally $r_n^js_{u_n}^j=(1-\alpha)\left(v_n^j-\bar{a}P_n^a\right)$ 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

$$\hat{u}_n^j = \underbrace{\hat{\rho}\,\hat{w}_n^j \hat{P}_n^{-1}}_{\text{Real Wages}} \cdot \underbrace{\hat{\Gamma}_n}_{\text{Subsistence}} \tag{32}$$

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 sector. We provide all results in the third panel of Table 20, which are not qualitatively different from the results in the second panel. In fact, the results are slightly stronger for trade cost reductions in the sense that they have a larger effect on GDP, and lead to larger migration flows (and therefore movements out of agriculture).

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 labor supply in addition to employment. Specifically, the total supply of effective labor

Table 20: Main Results With Non-Homothetic Preferences

Measured Change for	Trade Shares (p.p. Change) Internal	External	Migrant Stock Within Province	Between Province	Aggregate Outcomes Real GDP	Welfare
Baseline Model: Homothetic Preference						
Internal Trade	9.2	-0.7	0.8%	-1.8%	11.2%	11.4%
External Trade	-0.7	3.9	1.8%	2.4%	4.1%	2.9%
All Trade	8.2	2.8	2.5%	0.5%	15.2%	14.1%
Migration	0.1	0.1	14.5%	80.8%	4.8%	11.1%
Internal Changes	9.2	-0.6	15.1%	78.1%	16.4%	23.8%
Everything	8.3	3.0	16.9%	83.0%	20.8%	26.8%
Non-Homothetic Preferences						
Internal Trade	9.1	-0.7	4.4%	3.5%	12.4%	14.8%
External Trade	-0.6	3.7	4.3%	6.3%	5.7%	4.3%
All Trade	8.2	2.7	8.1%	8.6%	18.0%	18.9%
Migration	0.1	0.2	12.1%	70.1%	2.9%	8.3%
Internal Changes	9.1	-0.5	16.1%	76.8%	15.8%	24.8%
Everything	8.3	2.9	19.6%	85.5%	21.9%	29.6%

Notes: Displays the main counterfactual experiments with non-homothetic preferences.

in region n sector j is

$$H_n^j = \sum_{k\in\{ag,na\}} \sum_{i=1}^{N} \mu_{in}^{kj} \left(m_{in}^{kj}\right)^{-1/\kappa} m_{in}^{kj} \bar{L}_i^k., \tag{33}$$

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 labor 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

Table 21: Results with Worker Productivity Differences

Measured Change for	Trade Shares (p.p. Change) Internal	External	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	1.3%	-1.4%	-7.3%	9.5%	10.6%
External Trade	-0.7	3.9	2.4%	3.1%	5.0%	4.2%	2.1%
All Trade	8.3	2.9	3.5%	1.5%	-2.0%	13.8%	12.6%
Migration	0.3	-0.1	11.3%	57.4%	-14.5%	8.3%	1.2%
Internal Changes	9.5	-0.8	12.0%	55.7%	-19.5%	18.8%	12.1%
Everything	8.5	2.7	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	1.6%	-2.3%	-7.1%	9.4%	10.9%
External Trade	-0.6	3.9	2.8%	3.6%	5.8%	4.8%	2.5%
All Trade	8.3	2.9	4.2%	1.1%	-1.1%	14.2%	13.3%
Migration	0.3	-0.1	10.6%	63.3%	-0.9%	10.4%	2.0%
Internal Changes	9.5	-0.8	11.6%	59.9%	-6.6%	20.7%	13.3%
Everything	8.6	2.8	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.

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 workers. 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 21, 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, more productive. 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 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 $\hat{r}_n^j = \omega_n^j \hat{w}_n^j \hat{L}_n^j + 1 -$

Table 22: 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.

ω_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.

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 22. 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.