Trade, Migration and Regional Income Differences: Evidence from China

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Abstract

International trade is closely related to within-country trade and migration. To study these interrelationships, we develop a novel general equilibrium model of internal and external trade with migration, featuring both trade and migration frictions. We estimate these frictions using unique data on China's trade and migration; the costs are high, but declined after 2000. We quantify the consequences of lower trade costs (international and internal) and migration costs on welfare, internal migration, and regional income differences. External trade liberalization increases China's trade, but only modestly increases welfare while increasing regional income differences. Internal trade liberalization has large welfare gains and reduces regional income differences. Migration costs reductions dramatically increase migration and lower regional income differences but – surprisingly – only modestly increase trade and aggregate welfare, mainly because the migration costs remain very high. In a counterfactual exercise in which we lower the migration costs in China to the levels similar to those in the US, we find very large increases in both trade and aggregate welfare. Our results suggest internal reforms dominate external trade liberalization as a source of aggregate welfare gains and improvements in regional income inequality.

JEL Classification: F1, F4, R1, O4

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

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1 Introduction

International trade is closely related to within-country trade and migration. China's recent history provides an excellent opportunity to study these interrelationships. Since joining the World Trade Organization at the end of 2001, China's trade to GDP ratio has more than doubled, as has its internal trade between provinces, and worker migration is on a scale previously unknown in human history. Between 2000 and 2005, one hundred and eighteen million Chinese people switched counties and over forty million people switched provinces, primarily to work at coastal (export-oriented) manufacturing firms.[1] China is also unique in its system of internal mobility restrictions, with the *Hukou* household registration system dramatically increasing the costs of working and living outside your registration region (primarily through restricted access to social services or limited employment rights). Various reforms have started easing these restrictions, making migration less costly. These patterns raise a number of questions. How much of the worker migration flows are due to international trade liberalization? How much due to falling migration costs? Would China's export expansion still be possible without the large increase in migrant workers? More generally, how does external trade liberalization affect the spatial distribution of workers, production activities and income across regions within a country, and how does worker mobility affect trade and aggregate welfare?

To address these and other related questions, we develop a general equilibrium model of internal and external trade with migration, featuring both trade and migration frictions. These internal frictions are of first-order importance. Internal trade in China may face substantial costs (Young, 2000; Poncet, 2006). As previously mentioned, the *Hukou* registration system may severely limit worker mobility. A reflection of this friction to worker mobility is the large regional income disparity across the Chinese provinces. In 2000, the ratio of the income per worker for the 90th and 10th percentile provinces in China was 3.5. In contrast, the corresponding ratio for the US states is around 1.5 and one has to go back to the 19th century US to find cross-state income disparity that is similar to that in China. Therefore, any serious quantitative analysis of internal trade and migration in China has to take these frictions into account. To that end, we build on the recent work of Redding (2012) and Ahlfeldt et al. (2012). Following Redding (2012), we introduce within-country trade and worker mobility into the Eaton and Kortum (2002) model, and as Ahlfeldt et al. (2012) do for commuting decisions, we explicitly model worker location choices in the presence of migration costs. Workers are heterogeneous in their productivity across regions, providing for some incentive to migrate despite the costs while others choose to remain at home. Combining

[1]Perhaps the most well known example in China of export expansion with migrant workers is the case of Hon Hai Precision Industry (Foxconn). The rapid increase of Foxconn's workforce to assemble popular Apple products is predominantly due recruitment of migrant workers. At the company's facilities in Shenzhen, for example, which assemble iPhones and iPods at the Guanlan factory and iPads and Macs at the Longhua factory, migrant workers account for slightly over 99% of total employment. This pattern is not unique to Foxconn. Just north of Shenzhen, the city of Dongguan exemplifies China's changing economic environment. The city's total trade (imports plus exports) is nearly five times GDP and it alone accounts for a substantial fraction of global supply of computer and electronics components. Its expansion began from a population of 400,000 in 1978, largely engaged in farming and fishing, to over seven million in 2005. Of these seven million, over 70% are migrant workers (World Bank, 2009).

internal trade, external trade, and internal migration – with frictions to each – is novel. Even with these rich and realistic features, the model is analytically tractable and is easily implemented for quantitative analysis.

We fit this model to key features of China, mapping it directly into 30 individual provinces (we exclude Tibet for lack of data) and the rest of the world captured as a single external entity. Unique to our approach is the use of China's inter-regional input-output tables. The model calibration crucially depends on data for the full bilateral trading matrix between all provinces with each other and the world. This data has been exploited in other research, notably Poncet (2005), to estimate internal trade costs, but never to examine the relationship between trade and internal migration. Most model parameters have clear observable counterparts in the data, though the degree of worker productivity dispersion is both critical and non-trivial to calibrate. We use Census-level data on individual earnings to estimate the variation in productivity – following the approach of Cortes and Gallipoli (2014), who study a similar model in the context of occupational labour mobility. We use the full model to (1) measure the magnitude of trade and migration costs in the 2000/02 period; (2) changes in those costs over the years to 2005/07; and the consequences of these cost changes for trade flows, migration flows, real income differences between regions, and overall aggregate welfare. The dates ranges correspond to available data.

To estimated trade costs between provinces, we augment a Head-Ries index (Head and Ries, 2001) to incorporate systematic trade cost asymmetries, as in Waugh (2010). Trade costs are large, especially to import from abroad or from poorer regions of China; by 2005, these costs declined between 15-25%, especially to import from abroad or from poor regions. Migration data is compiled using the micro-data from China's Population Census 2000 and 2005. Combined with estimates of provincial real income (PPP adjusted across space) and our estimate of the migration elasticity, we estimate migration costs. They are substantial in 2000 – on the order of 90% of average income overall, and approximately 7% for migrants – and these costs declined only slightly by 2005.

What are the consequences of these measured changes in trade and migration costs? In a series of quantitative exercises using the fully calibrated model, we evaluate the effect of trade and migration cost changes on trade flows, the stock of migratnt workers, aggregate welfare, and regional income differences between provinces. Lower international trade costs increased the stock of migrants by less than 1% (compared to the 18% increase observed in data over the same period). Lower internal trade results about 2% fewer migrants, as workers move home. Both of these migration responses are small, though aggregate welfare responses are large – 7.3% in the case of internal trade reductions, 2.5% for external, and 9.6% for both. The large gains from internal trade are in contrast to small gains from international trade, which is a common feature of models of this type. In terms of regional income differences, internal trade costs lower variance in (log) real incomes across provinces by nearly 4% while lower international trade costs increase the variance by over 2%. Overall, the impact of international trade liberalization of China's growth is very modest.

Trade cost changes may account for very little change in the stock of migrant workers, but migration costs account for much more. The stock of migrants increases by over one-third in response to the lower measured migration costs. That being said, trade to GDP ratio and aggregate welfare barely change – increasing by only 0.1% and 0.1%, respectively. It is not that migration has no effect on trade and welfare, just that the amount of migration resulting from the small change in costs is low. To illustrate, consider the US, where approximately one-third of workers are outside their state of birth. Lowering migration costs in China uniformly to a level such that one-third of workers move outside their registration province, we find trade to GDP ratio increases by around 40%, welfare rises by over 12%, the stock of migrants increases by over 650%, and regional income differences decline nearly 60%. In any case, coupled with internal trade cost reductions, we clearly find that domestic reforms are substantially more important than external trade liberalization – they result in higher aggregate welfare, higher migration flows, and lower regional income differences.

Our work contributes to a recently growing literature linking international trade flows with the spatial distribution of labour within countries, such as Cosar and Fajgelbaum (2012); Redding (2012); Dix-Carneiro and Kovak (2014). Redding (2012), in particular, expands the Eaton-Kortum trade model to incorporate within-country regions between which labour can flow. He demonstrates that the welfare gains from trade depend not only on a region's home-bias but also on changes in the distribution of workers. Cosar and Fajgelbaum (2012) focus on firm, instead of worker, location decisions to link international liberalization with increased concentration of economic activity in areas with good market access. We build on the insights of these theoretical papers to quantitatively evaluate both trade and migration frictions applied to a unique setting. Also in this literature are papers investigating internal trade or migration costs, such as Morten and Oliveira (2014) or Ghani et al. (2012).

Our work is also related to empirical investigations of trade's effect on internal migration for other countries. McCaig and Pavcnik (2012) examine the 2001 US-Vietnam Bilateral Trade Agreement and document substantial worker flows towards internationally integrated industries and provinces, especially for younger workers. Research with individual Brazilian data establishes a positive relationship between internal migration flows and employment at foreign owned exporting establishments (Aguayo-Tellez and Muendler, 2009) and measures of a region's market access (Hering and Paillacar, 2012). There is also a large urban-economics literature investigating the role of international trade for altering the spatial distribution of firms and factors within a country (see, for example, Hanson, 1998). Little work has been done, however, investigating the case of China – perhaps the largest and fastest expansion of trade and internal migration ever recorded. Existing work for China typically abstracts from general equilibrium effects and investigates data only prior to 2000 (see, for example, Lin, Wang and Zhao, 2004 or Poncet, 2006). Our focus will be on developing a full general equilibrium model to quantitatively examine China's recent trade and migration patterns.

Our paper proceeds as follows. Section 2 documents China's internal migration flows, focusing on inter-provincial flows for economic reasons. This section also documents key internal trade relationships and regional differences in international trade exposure. Section 3 outlines and calibrates a modified Eaton-Kortum trade model that we use in Section 4 to infer the initial magnitude and changes in trade and migration costs. To gauge the quantitative effect of these changes, we explore various counterfactual experiments relating international trade costs, internal migration frictions, internal trade flows, and inter-provincial migration in China in Section 5. Following this, we explore some alternative modeling and estimation strategies in Section 6 – including the effect of migrant remittances – and find our main results robust. Section 7 concludes.

2 China's Internal Migration and Trade

We begin with a brief review of China's geography and its spatial differences in real incomes, stock of migrant workers, and trade flows. First, we briefly outline the policy environment within which workers make location decisions. We then document the magnitude of the stock of migrant workers, their characteristics and how there are distributed across regions in China. In addition to labour movements, there are large flows of goods between China's regions and provinces. We discuss the policies surrounding internal and external trade in China and document the trade data inferred from regional input-output tables.

2.1 Migration Policies

China's Hukou registration system impose significant barriers to labour mobility across provinces. Prior to 2003, all provinces in China had regulations that required workers without local Hukou to apply for a temporary residence permit. Due to the difficulty in getting the permit, many migrant workers were without a permit and faced the dire consequence of being arrested and deported by the local authorities. Due to the increasing demand for migrant workers in manufacturing and construction industries, many provinces, especially the coastal provinces, eliminated the requirement of temporary residence permit for migrant workers after 2003. This policy change probably helped to reduce the migration cost. However, most migrant workers still do not have access to the health, education and social services that are provided to residents with local Hukou. So the cost to labour mobility was reduced between 2000 and 2005, but barriers remain to be high. More importantly, migrant workers always face these costs as long as they do not have local *Hukou*.

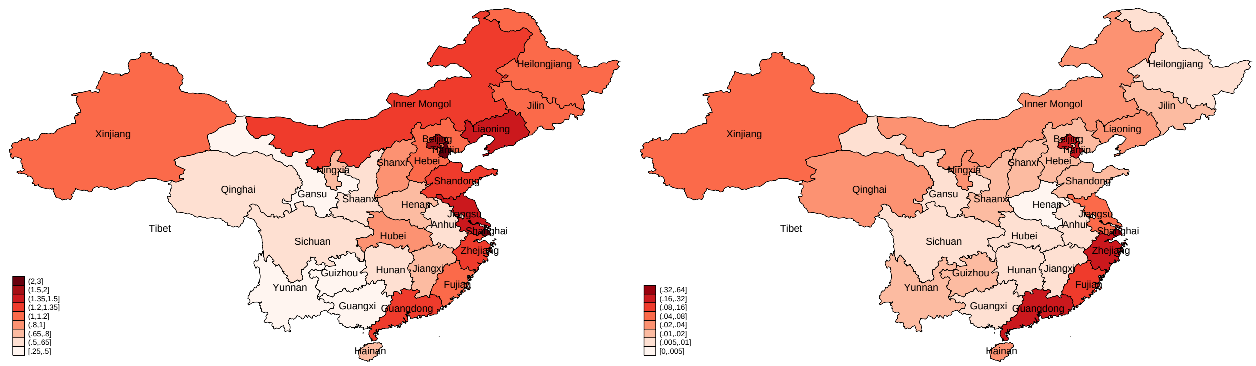
2.2 Characteristics of Inter-Provincial Migrants

In Figure 1, we display each measure as a choropleth by province. There are stark differences in real income levels across regions. Coastal regions have substantially higher levels of per capita income than interior regions; the 90/10 ratio is nearly 3.5. Migration flows are as one would expect: coastal regions have substantially higher shares of employment accounted for by migrant workers. If labour was perfectly mobile, though, we would expect substantially more migrants to arbitrage away the large income differences. That income differences persistent is suggestive

Figure 1: Spatial Distribution of Real Incomes and Migrant Labour in 2005

(a) Real GDP/Worker, Relative to Mean

(b) Inter-Provincial Migrant/Employment Ratio



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

evidence of non-trivial migration costs. We will return to a broad measure of migration costs later in the paper; next, consider the micro-characteristics of migrants from the Census.

We provide details behind the construction of migrant flows from the Population Census data in the appendix. Overall, between 2000 and 2005, there were 30.6 million inter-provincial migrant workers. Net migration flows by province are reported in Table 7. The census directly asks respondents who left their original *Hukou* registration place the reason for migrating. Table 1 displays key characteristics of inter-provincial migrants in China. Those individuals who are living in a location other than their original registration place number 165 million in 2005. Those living in a different province number over 53 million. The change in the total inter-provincial stock of migrants between 2000 and 2005 was 17.2 million.

Looking at the flow directly, we see a different pattern than the change in the total migrant stock. Between 2000 and 2005, nearly 118 million people moved out of their location of registration. Of those, 40.1 million moved across provincial boundaries. Restricting to those migrants who are employed, and who moved within the previous five years, lowers the number to nearly 31 million where over 93% say they moved for work. Other characteristics show that recent migrants are disproportionately those without children, coming from agricultural origins (as indicated by their registration type), working at private companies, and are roughly equally mixed between genders.

2.3 Trade Policies

Several researchers have documented high internal trade barriers in China in the 1990s (Young, 2000; Poncet, 2005). It has also been documented that the degree of local market protection in a province was directly related to the size of the state sector in that province (Bai, et. al., 2006). Since 2000, these trade barriers have been reduced significantly. Some of the reduction were due

Table 1: Migrant Characteristics (from Census Data)

(a) Migrant Stock

	1990	2000	2005
Total Migrants	32.7 M	130.6 M	165.4 M
Inter-Provincial Migrants	10.5 M	35.8 M	53 M
Inter-Provincial Migrant Workers	2 M	28 M	40 M

(b) Characteristics of Migrant Stock (Census 2005)

	All Migrants	Inter-Provincial Migrants	Employed Inter-Provincial Migrants
Number	165.4 M	53 M	40 M
Reason for Migrating			
Work	45%	73%	91%
Family	30%	21%	6%
Education	6%	2%	2%
Other	18%	4%	0.3%
Other Characteristics			
With Children	30%	28%	27%
Agricultural Hukou	62%	83%	86%
Male	50%	53%	57%
Private/Other Company	22%	40%	54%

(c) Five-Year Migrant Flow (Census 2005)

	All Migrants	Inter-Provincial Migrants	Employed Inter-Provincial Migrants
Number	117.5 M	40.1 M	30.6 M
Reason for Migrating			
Work	48%	75%	93%
Family	27%	19%	4%
Education	8%	2%	2%
Other	17%	4%	1%
Other Characteristics			
With Children	27%	26%	25%
Agricultural Hukou	66%	84%	87%
Male	50%	52%	56%
Private/Other Company	25%	44%	57%

Notes: Magnitude and characteristics of migrants, both as a stock and as a flow. Characteristics of the stock and the five year flow are from the 2005 Population Census of China. Migrants are defined based on their their *Hukou* registration location. "Private/other" company refers to employment at a private or other company – not at state, collective, or other enterprise and not self-employed.

to the deliberate policy reforms undertaking by the government. For example, the state council under the leadership of then premier Zhu Rongji issued a directive in 2001 that prohibits local government from engaging in local market protections (Holz, 2009). More importantly, as a result of SOE reform, the size of the state sector has declined significantly in almost all provinces and therefore reduced incentives for local governments to engage in local market protections. Finally The investment in transportation infrastructure and improvement in logistic technology also contributed to the decline in internal trade cost.

2.4 Internal and External Trade Patters

We extract province-level trade data, both between province pairs and internationally, from various regional input-output tables for 2002 and 2007.[2] The 2002 tables provide the full bilateral trade flow matrix between provinces as well as each provinces trade with the world. The 2007 tables report the same but for a restricted set of eight regions of China.[3] Measuring changes in trade patterns is therefore restricted to eight regions while initial 2002 trade patterns can be measured for all provinces. We provide further details in the appendix.

We report the bilateral flows between the eight regions and each other, and the rest of the world, for 2002 and 2007 in Table 2. 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. Each row will sum to one across columns. Some regions import substantially more from the rest of the world than they do from the other regions of China. Consider the South Coastal region, where many the Foxconn facilities discussed previously are located. This region imports over 2.5 times as much from abroad than it does from other regions within China. This region also exports substantially more than the rest of China. A useful summary measure of a region's trade openness is the fraction of its expenditures allocated to its own producers – that is, it's "home share." The diagonal elements of Table 2 provide these values for each region. Interior regions of China have much higher home-bias than coastal regions. In 2002, we estimate the central region's home-bias is 0.88 compared to only 0.72 for the south coast and 0.63 for Beijing and Tianjin.

All trade values reported so far are at the regional level. For 2002, though not for 2007, we compute trade shares for each individual province. These provincial-level trade patterns will play a crucial role in our quantitative exercises to come. We do not report the full matrix of bilateral relationships but list each province's home share in Table 7. Notably, and consistent with the regional data, interior provinces have higher home-bias than coastal provinces. In the second column of the same table, we report the ratio of total international exports to total gross output by province. Again, coastal regions have significantly greater fraction of production oriented towards international exports.

These measures, while interesting in their own right, will be key inputs into our later quantitative exercises and, importantly, provide information on the magnitude and patterns of trading costs both internal and external. We turn now to our complete model.

[2] We thank Zhi Wang for providing us with this data.

[3] 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).

Table 2: Regional Trade Patterns in China

Importer	Exporter								
	North-east	Beijing Tianjin	North Coast	Central Coast	South Coast	Central Region	North-west	South-west	Abroad
Year 2002									
Northeast	0.8789	0.0070	0.0099	0.0083	0.0134	0.0109	0.0077	0.0086	0.0553
Beijing/Tianjin	0.0392	0.6335	0.0936	0.0302	0.0261	0.0333	0.0138	0.0116	0.1188
North Coast	0.0183	0.0332	0.7984	0.0336	0.0176	0.0376	0.0092	0.0084	0.0437
Central Coast	0.0024	0.0016	0.0055	0.8101	0.0146	0.0238	0.0048	0.0046	0.1326
South Coast	0.0049	0.0039	0.0054	0.0262	0.7230	0.0193	0.0038	0.0151	0.1984
Central Region	0.0058	0.0026	0.0113	0.0476	0.0232	0.8777	0.0066	0.0071	0.0182
Northwest	0.0202	0.0077	0.0212	0.0325	0.0451	0.0356	0.7735	0.0378	0.0264
Southwest	0.0088	0.0034	0.0038	0.0182	0.0430	0.0137	0.0091	0.8803	0.0197
Abroad	0.0002	0.0003	0.0003	0.0013	0.0016	0.0001	0.0001	0.0001	0.9960
Year 2007									
Northeast	0.7871	0.0196	0.0201	0.0092	0.0271	0.0100	0.0137	0.0093	0.1040
Beijing/Tianjin	0.0376	0.6229	0.1006	0.0151	0.0236	0.0181	0.0207	0.0067	0.1545
North Coast	0.0205	0.0582	0.7679	0.0151	0.0154	0.0371	0.0227	0.0080	0.0550
Central Coast	0.0109	0.0073	0.0141	0.7678	0.0178	0.0484	0.0169	0.0085	0.1082
South Coast	0.0146	0.0086	0.0173	0.0516	0.6848	0.0360	0.0178	0.0284	0.1409
Central Region	0.0173	0.0142	0.0445	0.0485	0.0397	0.7297	0.0293	0.0176	0.0590
Northwest	0.0227	0.0220	0.0477	0.0271	0.0548	0.0356	0.6560	0.0359	0.0983
Southwest	0.0160	0.0116	0.0174	0.0165	0.0836	0.0188	0.0318	0.7378	0.0664
Abroad	0.0004	0.0007	0.0008	0.0037	0.0024	0.0003	0.0004	0.0002	0.9912

Note: Displays the share of each importing region's total spending allocated to each source region.

3 Quantitative Model

In this section, we develop a model of trade and migration building on Eaton and Kortum (2002). The model features multiple regions of China between which goods and labour may flow. Overall, the model is a departure from Redding (2012) in that we incorporate between-province migration frictions.

3.1 Heterogeneous Agents

There are $N+1$ regions representing China's provinces plus the rest of the world. In each region n, there is an initially endowed supply L_n^0 of workers, registered in region n, who can migrate across regions within China but not between China and the rest of the world. Workers differ in their productivity (or effective units of labour), so migration flows affect the supply of effective labour H_n in each region as well as the total number of workers L_n. We postpone a complete discussion of these migration decisions to section 3.3, as it suffices to take each region's aggregate effective labour supply H_n and employment as given for now.

Workers derive utility from a final good and residential housing structures. In effective-worker terms, the representative worker maximizes the Cobb-Douglas utility function $u_n = c_n^{\alpha} s_{u_n}^{1-\alpha}$ – where u, c, and s_u respectively denote utility, final goods, and housing structures per effective-worker – subject to a standard budget constraint $P_n c_n + r_n s_{u_n} \leq v_n$ – where P, r, and v respectively denote the final good price, the structure rental rate, and nominal income per effective-worker. Total consumption of final goods in region n is $c_n H_n$; likewise for structures used by workers. The u_n subscript of s_{u_n} distinguishes structures used by households from those used by firms (to come).

3.2 Production and Trade

A perfectly competitive firm produces final goods using the CES technology

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

where σ is the (constant) elasticity of substitution between individual varieties $Y_n(j)$, which may be sourced from local producers or imported.

Production of individual intermediate goods j is undertaken by firms in perfect competition that use labour, intermediate inputs, and land with the following technology

$$Y_n(j) = \varphi_n(j) H_n(j)^{\beta} S_{Yn}(j)^{\eta} Q_n(j)^{1-\beta-\eta},$$

where the firm's TFP is $\varphi_n(j)$, effective-labour $H_n(j)$, structures $S_{Yn}(j)$, and intermediate input $Q_n(j)$. This intermediate input comes from the total final goods available in region n; that is, $Y_n = c_n H_n + Q_n$, where Q_n is the total intermediates demanded by firms producing in region n.

Productivity differs across all firms and is modeled probabilistically, following Eaton and Kortum (2002). For each region, φ is distributed Frechet with CDF

$$F_i(\varphi) = e^{-T_i \varphi^{-\theta}},$$

dispersion parameter θ, and location parameter T_i. Productivity differences across goods j decrease in θ and increase in T_i. Importantly, the dispersion parameter θ must be common to all regions, both within-China and abroad. While this is a strong assumption, it is necessary to solve explicitly for trade shares and price indexes (to follow). Further, in the calibration to come, we argue the only existing within-country estimate of θ is close to the between-country estimates.[4]

A firm with productivity φ in region i would charge a purchaser in region n

$$p_{ni}(j) = \frac{\tau_{ni} w_i^{\beta} r_i^{\eta} P_i^{1-\beta-\eta}}{\varphi},$$

where $\tau_{ni} \geq 1$ is an iceberg trade cost, w_i are wages in region i, r_i is the price of structures, and P_i is the price for the final good.

Given this structure, purchasers in each region opt to source individual varieties $Y_n(j)$ from the lowest cost location. This results in expenditures being allocated across regions according to each region's technology, input costs, and trade costs. Denote π_{ni} the fraction of region n spending

[4] Caliendo et al. (2013) also assume a common θ between and within countries.

allocated to goods produced in region i. Given the Frechet distribution of technology,

$$\pi_{ni} = \frac{T_i \left(\tau_{ni} w_i^{\beta} r_i^{\eta} P_i^{1-\beta-\eta}\right)^{-\theta}}{\sum_{k=1}^{N+1} T_k \left(\tau_{nk} w_k^{\beta} r_k^{\eta} P_k^{1-\beta-\eta}\right)^{-\theta}}, \tag{1}$$

which results in a final good price

$$P_n = \gamma \left[\sum_{i=1}^{N+1} T_i \left(\tau_{ni} w_i^{\beta} r_i^{\eta} P_i^{1-\beta-\eta}\right)^{-\theta}\right]^{-1/\theta}, \tag{2}$$

where $\gamma = \Gamma\left(1 + \frac{1-\sigma}{\theta}\right)^{1/(1-\sigma)}$.

3.3 Internal Labour Migration

Labour is mobile only between regions within China, not between any Chinese province and the world and vice-versa. For each worker, there is one (and only one) home (or, in China's case, *Hukou*) region. It is costless to live within one's home region but a migrant worker with home region n faces a cost to live in region $i \neq n$. We model these costs as proportional to income, where a share $1 - \mu_{ni}$ of income in region i is lost due to migration costs. This migration costs is a *real* cost, and can be considered a reduction in a migrant's productivity due to the move or a loss in time available for work. In addition, workers have heterogeneous productivity that differ by region (or, equivalently, they differ in their migration costs), creating differences in worker migration incentives. Formally, workers draw at birth a vector $\{z_n\}_{n=1}^{N}$ of productivity for each region $n \in \{1, N\}$, which are i.i.d. across workers and regions. Workers then choose where to live to maximize their real income net of migration costs $\mu_{ni} z_i V_i$.[5]

With this structure, it is straightforward to solve for migration flows. A worker from region n will migrate to region i if and only if

$$\mu_{ni} z_i V_i > \max_{k \neq i} \{\mu_{nk} z_k V_k\}.$$

As z_j is a random variable across the continuum of individuals from region n, the law of large numbers ensures the proportion of region n workers who migrate to region i is

$$m_{ni} = Pr\left(\mu_{ni} z_i V_i \geq \max_{k \neq i} \{\mu_{nk} z_k V_k\}\right).$$

For a particular distribution of productivity, this proportion can be solved explicitly. Assume that

[5] This approach closely follows recent work by Artuc, Chaudhuri and McLaren (2010) and Ahlfeldt, Redding, Sturm and Wolf (2012). Morten and Oliveira (2014) use a similar approach, though in a very different context.

productivity follow a Frechet distribution with CDF

$$F_z(x) = e^{-x^{-\kappa}},$$

where κ governs the degree of dispersion across individuals. A large κ implies little dispersion. The mean of this distribution is $\tilde{\gamma} = \Gamma\left(1 - \kappa^{-1}\right)$, where Γ denotes the Gamma function; it plays little role in the quantitative analysis to come, as what matter is *relative* worker productivity. Notice the similarity to firm productivity from the previous section; many of the results to come for worker migration will be familiar. The usefulness of this particular distribution is demonstrated in the following proposition.

Proposition 1 *Given real incomes for each region V_i, migration costs between all regional pairs μ_{ni}, and heterogeneous productivity distributed $F_z(x)$, the share of region n workers that migrate to region i is*

$$m_{ni} = \frac{\left(V_i \mu_{ni}\right)^{\kappa}}{\sum_{k=1}^{N} \left(V_k \mu_{nk}\right)^{\kappa}}. \tag{3}$$

Proof: See appendix.

With migration shares from equation 3, the number of workers in each region is

$$L_n = \sum_{i=1}^{N} m_{in} L_i^0. \tag{4}$$

This measures migration relative to individual's original *Hukou* registration province. This presumes persistent migration costs μ_{in} for workers with *Hukou* registration in province i that moves into province n. The costs do not change for this individual after the move – migration decisions are always taken relative to the original *Hukou* registration province not the current province of residence. This implies (1) it is costless for migrants to return to their *Hukou* province and (2) costs of living outside of the *Hukou* province are perpetually incurred (not once and for all upon migration).

With the migration decisions fully characterized, we can solve for the effective labour supply in each region H_n.

Proposition 2 *The total supply of effective labour in region n is*

$$H_n = \sum_{i=1}^{N} \tilde{\gamma} \mu_{in} m_{in}^{\frac{\kappa-1}{\kappa}} L_i^0. \tag{5}$$

Moreover, $h_{in} = \tilde{\gamma} m_{in}^{-1/\kappa}$ is the average units of effective labour for workers from region n that work in region i, and therefore $H_n = \sum_{i=1}^{N} \mu_{in} h_{in} m_{in} L_i^0$.

Proof: See appendix.

3.4 Real Income per Effective Worker

For simplicity, all payments to structures in a given region are rebated to the workers of that region in proportion to their units of effective-labour.[6] Total income in region n is then

$$v_n H_n = w_n H_n + (1-\alpha) v_n H_n + \eta R_n,$$

where R_n is total revenue from all producing firms in region n. In this expression, v_n denotes nominal income per effective worker. As the production technologies for individual varieties are Cobb-Douglas, a constant fraction β of revenue is spent on labour inputs. Nominal income per effective worker in region n is

$$v_n = \left(\frac{\beta+\eta}{\alpha\beta}\right) w_n, \tag{6}$$

and real income is

$$V_n = \frac{v_n}{P_n^{\alpha} r_n^{1-\alpha}}. \tag{7}$$

To solve for the cost-of-living in region n, and therefore the real income expression, note that land market clearing implies

$$r_n = \left(\frac{(1-\alpha)\beta+\eta}{\alpha\beta}\right) \frac{w_n H_n}{S_n}, \tag{8}$$

where $S_n = s_{u_n} H_n + S_{Yn}$ is the total stock of structures in region n. Combined with the final good prices, real incomes is

$$V_n \propto (T_n/\pi_{nn})^{\frac{\alpha}{\theta(\beta+\eta)}} s_n^{\frac{\eta+(1-\alpha)\beta}{\beta+\eta}},$$

where s_n denotes structures per effective worker and the proportionality constant is common across all $N+1$ regions. This shows the two key channels for increases in a region's real income: (1) lower home-share π_{nn} and (2) higher structures per effective worker s_n. The first follows from heterogeneous productivity of firms within a region. Imports can substitute for low productivity domestic producers. The second channel is influenced by migration flows. Inward migration make structures increasingly scarce, and therefore more costly, lowering real incomes.

Combine these results with trade shares π_{ni} to determine equilibrium wages and therefore nominal income in each region. Total revenue in each region equals total sales to all consumers in every other region. Total expenditures on goods are from households (αv_n) and firms $(1-\beta-\eta)R_n$. Since π_{ni} is the share of spending by region n allocated to goods from region i,

$$\begin{aligned} R_n &= \sum_{i=1}^{N+1} \pi_{in} \left(\alpha v_i H_i + (1-\beta-\eta) R_i\right), \\ &= \sum_{i=1}^{N+1} \pi_{in} R_i, \end{aligned}$$

[6] Equivalently, a government collects rental payments and rebates them through a wage subsidy.

where the second line follows from $R_i = w_n H_n / \beta$ and from equation 6.

3.5 Aggregate Welfare and Migrant Real Income Shares

Real income and welfare are synonymous in our framework. The following proposition determines expected real income for each region of registration and the aggregate (registration-weighted) average real income.

Proposition 3 *If worker productivity z_i is distributed Frechet with variance parameter κ, and agents are able to migrate between regions at cost μ_{ni}, then the expected real income net of migration costs for workers from region n is*

$$V_n^0 = \tilde{\gamma} V_n m_{nn}^{-1/\kappa},$$

and aggregate average real income (welfare) is therefore

$$W = \tilde{\gamma} \sum_{n=1}^{N} \lambda_n^0 V_n m_{nn}^{-1/\kappa},$$

where $\tilde{\gamma} = \Gamma\left(1 - \kappa^{-1}\right)$ and $\lambda_n^0 = \frac{L_n^0}{\sum_{i=1}^N L_i^0}$ is the share registered in region i.

Proof: See appendix.

Combine these results with Proposition 2 to find,

Corollary 1 *The worker migration shares m_{ni} also represents the share of total real income earned by all n-registered workers earned by those working in region i.*

Proof: Substitute m_{in} (and m_{ii}) from equation 3 into equation 5 to get

$$\begin{aligned} H_n V_n &= \sum_{i=1}^{N} \tilde{\gamma} \left[\sum_{k=1}^{N} \left(V_k \mu_{ik} \right)^{\kappa} \right]^{1/\kappa} m_{in} L_i^0, \\ &= \sum_{i=1}^{N} \tilde{\gamma} V_i m_{ii}^{-1/\kappa} m_{in} L_i^0, \\ &= \sum_{i=1}^{N} m_{in} V_i^0 L_i^0. \end{aligned}$$

Since $H_n V_n$ is total real income earned by workers in region n, and $V_i^0 L_i^0$ is the total real income earned by all workers registered in region i, we have our result. ■

This property of migration shares is analogous to trade shares π_{ni}, which – as is well known – are not only the share of region n expenditure allocated to goods from i but also the share of varieties consumed by n that originate from i. Similarly, since worker productivity draws are i.i.d. across individuals and regions, m_{ni} is both the fraction of workers from n that migrate to i and the fraction of income earned by all workers from n from those who migrated to i. If the expected real income of workers registered in region i is V_i^0 then $m_{in}L_i^0V_i^0$ is from those workers who migrated to region n. This property will prove useful.

With the initial equilibrium now fully characterized, we move on to express how the model responds to changes in exogenous parameters.

3.6 Counterfactual Relative Changes

To ease our quantitative analysis and calibration, we follow Dekle, Eaton and Kortum (2007) and express counterfactual values relative to initial equilibrium values. That is, let $\hat{x} = x'/x$, where x' is the counterfactual value of x. The following system of equations solves for changes in prices ($\hat{P}_n$), trade flows ($\hat{\pi}_{ni}$), and wages ($\hat{w}_n$) and real income ($\hat{V}_n$) per effective worker as a function of changes in trade costs ($\hat{\tau}_{ni}$), underlying productivity ($\hat{T}_n$), and effective labour ($\hat{H}_n$):

$$\hat{w}_n \hat{H}_n R_n = \sum_{i=1}^{N+1} \pi'_{in} \hat{w}_i \hat{H}_i R_i, \tag{9}$$

$$\pi'_{ni} = \frac{\pi_{ni}\hat{T}_i \left(\hat{\tau}_{ni}\hat{w}_i^{\beta+\eta}\hat{P}_i^{1-\beta-\eta}\hat{H}_i^{\eta}\right)^{-\theta}}{\sum_{k=1}^{N+1}\pi_{nk}\hat{T}_k\left(\hat{\tau}_{nk}\hat{w}_k^{\beta+\eta}\hat{P}_k^{1-\beta-\eta}\hat{H}_k^{\eta}\right)^{-\theta}}, \tag{10}$$

$$\hat{P}_n = \left[\sum_{k=1}^{N+1}\pi_{nk}\hat{T}_k\left(\hat{\tau}_{nk}\hat{w}_k^{\beta+\eta}\hat{P}_k^{1-\beta-\eta}\hat{H}_k^{\eta}\right)^{-\theta}\right]^{-1/\theta}, \tag{11}$$

$$\hat{V}_n = \frac{\hat{w}_n^{\alpha}}{\hat{P}_n^{\alpha}\hat{H}_n^{1-\alpha}}, \tag{12}$$

which hold for all regions both within China and abroad. Within China, counterfactual employment L'_n and effective labour H'_n are similarly defined by

$$m'_{in} = \frac{m_{in}\left(\hat{V}_n\hat{\mu}_{in}\right)^{\kappa}}{\sum_{k=1}^{N} m_{ik}\left(\hat{V}_k\hat{\mu}_{ik}\right)^{\kappa}}, \tag{13}$$

$$H'_nV'_n = \tilde{\gamma}\sum_{i=1}^{N} m'_{in}L_i^0V'_i\ {m'_{ii}}^{-1/\kappa}, \tag{14}$$

with $V'_n = \hat{V}_nV_n$ and $H'_n = \hat{H}_nH_n$. Importantly, equations 13 and 14 only hold within China. For the rest of the world, $\hat{L}_{1+N} = \hat{H}_{1+N} = 1$, as workers cannot move across national boundaries by assumption.

The solution to the above system can also be used to capture changes in other relevant objects; namely, employment and aggregate welfare. Counterfactual employment L'_n (rather than effective labour H'_n) is given by $L'_n = \sum_{i=1}^{N} m'_{in}L_i^0$. Aggregate welfare changes follow from proposition 3; it is straightforward to show $\hat{W} = \sum_{i=1}^{N}\omega_i\hat{V}_i\hat{m}_{ii}^{-1/\kappa}$, where $\omega_i = \frac{\lambda_i^0V_im_{ii}^{-1/\kappa}}{\sum_{j=1}^{N}\lambda_j^0V_jm_{jj}^{-1/\kappa}}$. We will also report changes in aggregate real GDP. This is simply the weighted average changes in real value of total output across provinces, with weights equal to the initial equilibrium share of national output in each province. Since value-added shares $\beta + \eta$ are identical across provinces, and total nominal output is proportional to the wage bill, the initial share (the weights) is $e_n = R_n / \sum_{i=1}^{N} R_i$. The aggregate change in real GDP is then

$$\hat{Y} = \sum_{n=1}^{N} e_n \frac{\hat{R}_n}{\hat{P}_n} = \sum_{n=1}^{N} e_n \left(\frac{\hat{w}_n}{\hat{P}_n} \right) \hat{H}_n. \tag{15}$$

The complexity of the above system demands further discussion. The model provides a mapping from cost and productivity changes $(\hat{\tau}_{ni}, \hat{\mu}_{ni}, \hat{T}_n)$ to outcomes $(\hat{P}_n, \hat{w}_n, \hat{\pi}_{ni}, \hat{V}_n, m'_{ni}, L'_n, H'_n)$, given parameters $(\alpha, \beta, \eta, \theta, \kappa)$ and certain initial values $(Y_n, \pi_{ni}, m_{ni}, L^0_i, V_n, H_n)$. Given certain observable outcomes from data, we can infer the underlying changes in costs and productivity – the focus of section 4. We can also simulate changes in outcomes for a subset of changes in costs and productivity – the focus of section 5. For example, to examine the effect of changes in internal trade costs only set $\hat{\mu}_{ni} = \hat{T}_n = 1$ for regions and pairs, $\hat{\tau}_{ni} = 1$ for $n = 1 + N$ or $i = 1 + N$, and all other $\hat{\tau}_{ni}$ equal to what we measure. The change in outcomes then reflect the effect of internal trade cost changes alone. Notice we need not estimate initial values for S_n, T_n, or even τ_{ni} or c_{ij}; this substantially simplifies the calibration and quantitative exercises to come. Once parameters and initial values are calibrated, the model becomes a powerful quantitative tool.

3.7 Calibrating the Model

In this section, we calibrate the model in an empirically reasonable way. The equilibrium system in equations 9 through 14 takes parameters $(\alpha, \beta, \eta, \theta, \kappa)$ and certain initial values $(X_n, \pi_{ni}, m_{ni}, L^0_i, V_n, H_n)$ as given. The parameters include the preference weight on goods consumption (α), labour's share of output (β), land's share of output (η), and parameters governing the variance of the firm productivity distribution (θ) and the worker productivity distribution (κ). The remaining parameters include a region's initial total revenue R_i, trade shares π_{ni}, migration shares m_{ni}, Hukou registrations L^0_n, real income per effective worker V_n, and finally the stock of effective labour H_n. We describe the calibration in the subsections that follow and provide a brief summary in Table 3.

3.7.1 Parameters Observable from Data

The utility and production function parameters (α, β, η) are set such that labour's share of gross output is 20% and intermediate input's share is 60%. Land and structure's share follows from our constant returns to scale assumption, and thus $\eta = 0.2$. The 2002 extended input-output tables of China list total labour compensation, total intermediate input use, and gross output. The ratio of intermediate input use to gross output is 0.6112; we round to 0.6. We assume labour's share is larger than the ratio of labour compensation to gross output (approximately 0.2 in the input-output data) to reflect machinery and human capital used by workers, and set $\beta = 0.3$, which implies $\eta = 0.1$. Finally, to calibrate α, we use consumer expenditure data from China's

Table 3: Calibrated Model Parameters and Initial Values

Parameter	Value	Target / Description
β	0.3	Labour's share of gross output
η	0.1	Intermediate share of output of 0.6
α	0.87	Housing share of expenditure of 0.13
θ	4	Elasticity of Trade
κ	2.21	Income-Elasticity of Migration
X_n	*Region Specific*	Initial nominal expenditures
π_{ni}	*Pair Specific*	Bilateral trade shares
m_{ni}	*Pair Specific*	Bilateral migration shares
L_n^0	*Region Specific*	Hukou registrations
V_n	*Region Specific*	Initial real income per effective worker
H_n	*Region Specific*	Initial stock of effective workers

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

most recent National Statistical Yearbook. The fraction of urban household spending on housing is 11.30% and for rural households is 15.47%. As a compromise between these values, we set $\alpha = 0.87$, implying the housing share of expenditures is 13%.[7]

The home/Hukou province for workers L_n^0 are straightforward and observable from China's 2000 Population Census, where province of registration is a direct question. We list the distribution of Hukou registrations by province in Table 11. Total national employment for China is 636.508 million. Total employment in the rest of the world (which is also L_{N+1}^0, since international migration is absent) is 2,103 million. This is inferred from the Penn World Table as the total non-China employment for the same year.

3.7.2 Cost-Elasticity of Trade

The productivity dispersion parameter θ has received a great deal of attention in the literature. This parameter governs productivity dispersion across firms and, consequently, determines the sensitivity of trade flows to trade costs (higher θ implies *lower* elasticity). Between-countries, there are many estimates of this elasticity to draw upon. Anderson and van Wincoop (2004) review the literature and argue a value for θ between 5 and 10 is reasonable. For example, using cross-country price differences, Eaton and Kortum (2002) estimate $\theta = 8.3$; using the same procedure, Waugh (2010) finds $\theta = 7.9$ for OECD countries. Recently, however, Simonovska and Waugh (2011) improve upon the price-differences method and find $\theta \approx 4$. Using a new approach linking triple-differenced tariffs to triple-differenced trade flows, Parro (2013) estimates $\theta \in [4.5, 5.2]$ for manufacturing; using this same procedure for agriculture, Tombe (2014) estimates $\theta = 4.1$. Within-countries, however, there is little evidence to draw upon. We are aware of only one within-country estimate based on firm-level productivity dispersion in the US, where Bernard et al. (2003) estimate $\theta = 3.6$. As there is a strong consensus that $\theta = 4$ (or thereabouts) is a reasonable estimate

[7] This number is not selected at random between 0.113 and 0.1547. It is also the weight given to housing in the spatial consumer price level data that we will employ later in the paper.

for the trade elasticity, we set $\theta = 4$.

3.7.3 Income-Elasticity of Aggregate Migration

Similar to the cost-elasticity of trade is the income-elasticity of aggregate migration κ. There are unfortunately few estimates of this elasticity, though we can bound its magnitude. This elasticity should be bounded below by 2, since this ensures a finite variance of worker productivity. As an upper bound, consider Ahlfeldt et al. (2012)'s estimate of $\kappa \in [4.8, 6.5]$ for the cost-elasticity of commuting (not migration) within Germany following the collapse of the Berlin Wall. As commuting decisions are likely more sensitive to income than inter-provincial migration, where both residence and work location change, our estimate of κ should be below theirs.

How do we proceed to estimate a more precise value for this parameter? The elasticity of migration is driven by the degree of heterogeneity in region-specific productivity across workers; given the Frechet distribution of productivity, the proof of Proposition 3 provides a means of estimating κ from individual earnings data. First exploited by Cortes and Gallipoli (2014) in a different context, notice that *after* migration decisions are made, ex-post earnings across individuals are distributed according to $F_{U_i}(x)$ – which is 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

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

which has a standard deviation $\pi/(\kappa\sqrt{6})$. Importantly, the standard deviation of earnings is independent of μ_{ni} and V_i, so is common across locations.

How do we estimate this standard deviation from data? In the Census data, we have nominal earnings $\mu_{ni}z_i v_i$. The above expression, however, applies to *real* earnings $\mu_{ni}z_i V_i$. Real earnings are $V_i = v_i/P_i^{\alpha} r_i^{1-\alpha}$ and the denominator is common to all workers in region i; therefore, $var(log(z_i V_i)) = var(log(z_i v_i))$ between workers within each region i. Next, μ_{ni} is common to all workers from region n working in region i; therefore, $var(log(\mu_{ni}z_i v_i)) = var(log(\mu_{ni}z_i v_i))$ between workers within each (n, i) pair. We can therefore identify the value of κ from the within-group nominal earnings variation, with groups defined as worker source (Hukou-region) and current location pairs. From Census 2005, we find an average within-group standard deviation of log earnings of 0.58, which implies $\kappa = 2.21$.[8] This will be our baseline value for κ, though at the end of the paper we explore the sensitivity of our results to alternative (larger) values; all key

[8]Controlling for individual characteristics has little affect on these results. To control for these differences, define the vector of worker k's characteristics in region j as $\mathbf{X}_{k,j}$, and run

$$log(z_{k,j}v_{k,j}) = \rho_{ij} + \beta\mathbf{X}_{k,j} + \epsilon_{k,ij},$$

where k denotes an individual worker observation with Hukou registration in region i and currently works in region j; the parameter ρ_{ij} is a fixed effect for each source and current location pairs. The set of individual controls here includes education, occupation, industry, marital status, age (and age squared), gender, literacy status, Hukou type (agricultural or non-agricultural), and their health condition. The *residual* of this regression $\hat{\epsilon}_{k,ij}$ is the earnings unexplained by individual characteristics or source-location migration patterns. We find the standard deviation of $\hat{\epsilon}_{k,ij}$ equal to 0.45, which in this case implies $\kappa = 2.85$.

results are robust.

3.7.4 Initial Expenditures, Incomes, and Effective Workers

To solve equation 9, we require a value for region n's initial total revenue, R_n. Given regional data on trade and employment, we find the value of R_n that solves the initial trade balance condition

$$R_n = \sum_{i=1}^{N+1} \pi_{in} R_i.$$

To do this, we use province level data on trade π_{ni} from China's extended 2002 input-output tables. We do not report the entire matrix here, but one can get a sense for the value of π_{ni} for each province by reviewing the regional trade patterns from Section 2.4. The solution to this is the total revenue, expenditures, and *nominal* income for each region, up to a constant. We normalize total nominal revenue across all of China's provinces to one: $\sum_{n=1}^{N} R_n = 1$ and list the values in Table 11. Given this normalization, the initial share of GDP in each province is R_n and therefore the weights $e_n = R_n$ in the aggregate real GDP change – equation 15.

Proposition 3, together with Corollary 1, are very useful to solve initial stocks of effective workers and the initial real income per effective worker in each region. We can use data on real incomes in each region to solve for H_n and V_n without knowing bilateral migration costs μ_{ni} – unlike Proposition 2. Specifically,

$$(H_n V_n)^{data} = \sum_{i=1}^{N} \tilde{\gamma} V_i m_{ii}^{-1/\kappa} m_{in} L_i^0, \tag{16}$$

solves for V_i given real income and migration data. With this, back out $H_n = (H_n V_n)^{data} / V_n$. We provide values for both variables in Table 11.

4 Inferring Trade and Migration Costs

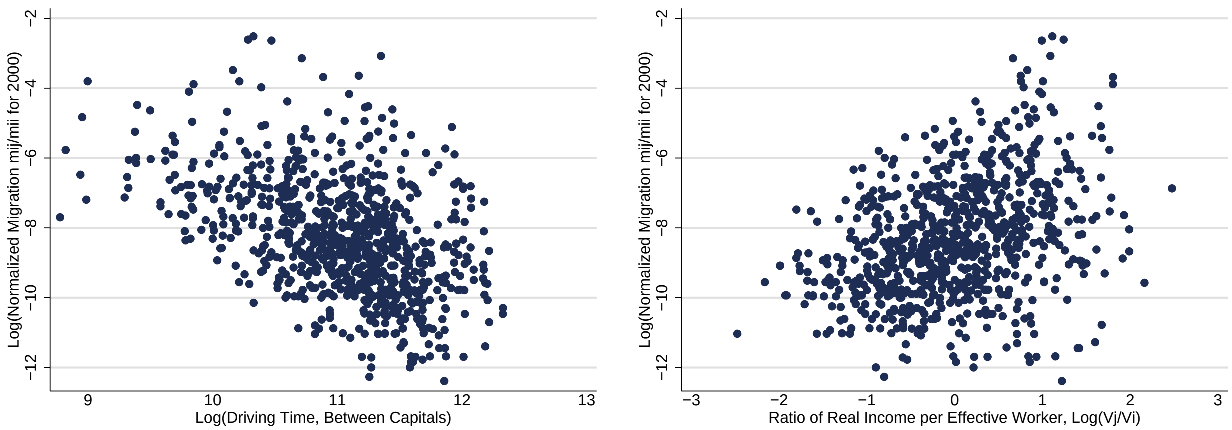
In this section, we quantify the extent of migration costs within China and trade costs within and between China's provinces and the world.

4.1 Migration Costs

Recall the expression from equation 3, $m_{ni} = (V_i \mu_{ni})^{\kappa} / \left(\sum_{k=1}^{N} (V_k \mu_{nk})^{\kappa} \right)$, governing the flow of workers between China's provinces. This representation of migration decisions is simple yet powerful. Migration flows in data, for example, do respond to what is surely a particularly import component of migration costs: distance to home. In Figure 2(a) we plot a normalized measure of migration $ln(m_{ni}/m_{nn})$ against the time required to drive between each province's capital cities. Driving time is a slightly better predictor of migration than great circle distances. Migration flows

Figure 2: Migration Flows, Distances, and Real Income Differences

(a) Migration vs. Travel Time (b) Migration vs. Income Differences



Notes: Displays the relationship between normalized migration $log(m_{ij}/m_{ii})$ in 2000 and (1) travel time and (2) income differences. Travel time is measured as the driving time between provincial capitals, calculated from the Google Maps API. Income differences are the log ratio of real income per effective worker in the destination province to real income per effective worker in the home province; that is, $log(V_j/V_i)$.

are clearly smaller between provincial pairs that are far apart. Also, migration flows respond positively to real income differences. In Figure 2(b) we plot the same measure of normalized migration against real incomes per effective worker $log(V_i/V_n)$. Migrants flow towards provinces that have higher real incomes relative to their home province.

We can more completely characterize migration costs. With real incomes V, migration shares m, and the dispersion parameter κ we have

$$\mu_{ni} = \left(\frac{m_{ni}}{m_{nn}}\right)^{1/\kappa} \frac{V_n}{V_i}. \tag{17}$$

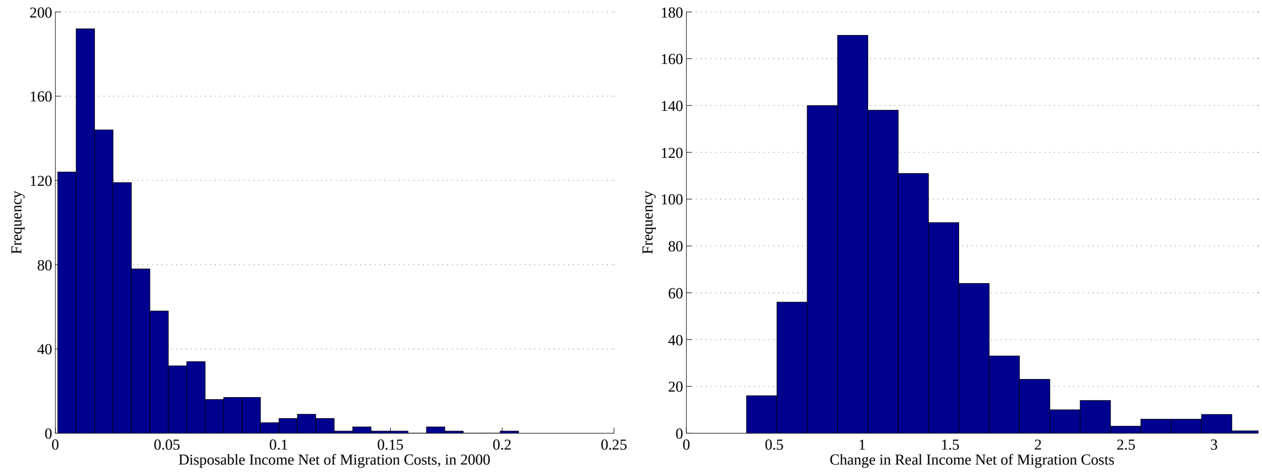
Based on our calibrated value of $\kappa = 2.21$ from section 3.7, we find migration costs declined for most pairs of provinces in China. We display the histogram of both the initial post-migration cost income share μ_{ni} and its relative change $\hat{\mu}_{ni}$ in Figure 3. Migration costs are large. In 2000, we estimate that over 93% of income is paid as migration costs, though there are large differences between pairs. That being said, the migration costs for *migrants* is substantially less, as workers have different productivity in different regions.[9] To get at this, consider the z draws as worker-specific differences in the real cost of migrating. The average real income net of migration costs for migrants is then $E\left[\mu_{ni} z_i \mid \text{migrate from } n \text{ to } i\right]$. The migrant-weighted average for this across all of China is 0.9337, suggesting that once we account for z the average migration cost for migrants is approximately 7%.

In Figure 4, we plot the spatial distribution of migration costs for two example cases: inflows

[9]The distinction between overall migration costs and migration costs for *migrants* is also emphasized by Kennan and Walker (2011).

Figure 3: Histogram of Bilateral Migration Costs

(a) Migration Cost Parameter μ_{ij} in 2000 (b) Relative Changes in μ_{ij}



Notes: Displays the measure of migration costs captured by the fraction of income remaining after migration costs are paid. We denote this value as μ_{ij} in the text. Panel (b) displays the ratio of μ_{ij} in 2005 to its year 2000 level. Values for relative changes above one represent *reductions* in migration costs.

to Beijing and outflows from Sichuan. These choropleths represent the magnitude of trade costs $(1 - \mu_{ni})$ in terms of color intensity. In panel (a), it is clear that provinces far from Beijing typically have higher costs to move into Beijing. This is also true for outflows. Panel (b) shows the costs of migrating out of Sichuan is largest for the northeastern regions. These large costs across space prevent workers from arbitraging large differences in real income across regions.

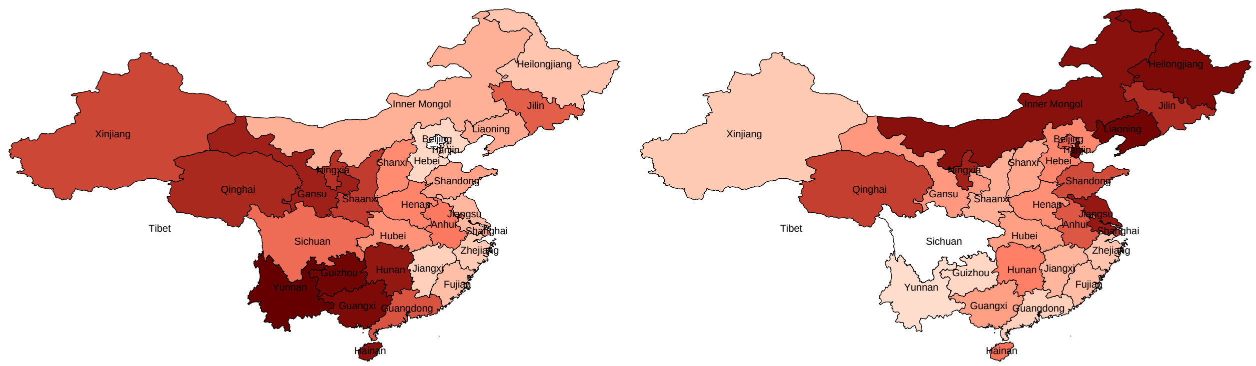
The relative changes in migration costs are particularly relevant for our quantitative exercises. Using the ratio of equation 17 evaluated with 2005 and 2000 data, we infer these changes from real income and migrant flow changes between 2000 and 2005. We display the results in panel (b) of Figure 3. Approximately two-thirds of pairs experience reductions in costs ($\hat{\mu}_{ni} > 1$), with an average value of $\hat{\mu}_{ni} = 1.49$. Among the 36% of pairs for which migration costs increased, we find an average value of $\hat{\mu}_{ni} = 0.79$. Overall, the typical pair experienced a change in migration costs of $\hat{\mu}_{ni} = 1.24$. That is, the share of income kept by migrants after paying migration costs increased by 24%. These estimates for $\hat{\mu}_{ni}$ are similar within a wide range of values for κ.

4.2 Trade Costs

Before discussing how we estimate trade costs, it is useful to define key terms that will recur throughout the paper. First, denote costs for region n to import goods from region i as $\tau_{ni} \geq 1$. This is a gross measure, so $\bar{\tau}_{ni} = 1.1$ implies a 10% tariff-equivalent trade costs. Second, trade patterns will be reflected in how total expenditures by each region are allocated across possible producers. Let π_{ni} be the share of region n spending allocated to goods from region i. Similarly, π_{nn} is the share allocated to its own domestic producers – region n's home-share. Finally, how

Figure 4: Selected Spatial Distributions of Migration Costs

(a) Costs of Migrating *Into* Beijing (b) Costs of Migrating *Out of* Sichuan



Notes: Displays choropleths of selected migration costs into Beijing (a common destination for migrants) and out of Sichuan (a common source of migrants). The darker the red, the higher the migration cost. Tibet excluded.

sensitive trade flows are to trade costs (the elasticity of trade) is given by θ.

With these terms in hand, we estimate trade costs using a recent method developed in Head and Ries (2001) and later generalized by Novy (2013). This method applies to a broad class of trade models, including the model we develop in section 3. While we omit the full derivation, it is straightforward to show the average trade costs between region n and i is

$$\bar{\tau}_{ni} \equiv \sqrt{\tau_{ni}\tau_{in}} = \left(\frac{\pi_{nn}\pi_{ii}}{\pi_{ni}\pi_{in}}\right)^{1/2\theta}. \tag{18}$$

Interested readers can jump to equation 1 to see this.

This method has a number of advantages. First, note that trade shares are normalized by home-shares and therefore $\bar{\tau}_{ni}$ is not affected by trade volumes or by third-party effects. It also applies equally well whether trade balances or not. For example, if region i experiences a massive increase in trade with some other region k, say due to lower trade costs between i and k, then region i will lower its trade with region n *by the same proportion* as it lowers its purchases from itself. The estimated trade costs between i and n is therefore unaffected. With such advantages, this approach is increasingly employed to estimate trade costs (Jacks et al., 2008, 2010, 2011; Miroudot et al., 2012; Caliendo et al., 2013; Tombe, 2014). It is also the method behind the World Bank's UNESCAP Trade Cost Database.

Unfortunately, these trade cost estimates are symmetric in the sense that goods moving from i to n face the same impediments as goods moving from n to i. With some additional structure, we can estimate trade cost asymmetries. Following Waugh (2010), we presume all asymmetries take the form of exporter-specific costs; that is, $\tau_{ni} = t_{ni}t_i$, where t_{ni} are symmetric costs ($t_{ni} = t_{in}$) and t_i are deviations from these symmetric costs that are specific to the exporter.[10] With an estimate for t_i,

[10] This formulation is consistent with Tombe and Winter (2014), who use demonstrate that Waugh (2010) for trade internal within-country trade.

we can adjust the symmetric trade cost measure $\bar{\tau}_{ni}$ from equation 18 to reflect these asymmetries; specifically, $\tau_{ni} = \bar{\tau}_{ni}\sqrt{t_i/t_n}$.

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 given by

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

where S captures any country-specific factor affecting competitiveness, such as factor prices or productivity.[11] If trade costs have only a symmetric and exporter-specific component, and therefore $\tau_{ni} = t_{ni}t_i$, then we can estimate t_i from

$$ln\left(\frac{\pi_{ni}}{\pi_{nn}}\right) = \rho_{ni} + \iota_n + \eta_i + \epsilon_{ni}, \tag{19}$$

where ρ_{ni} is a directionless pair-effect such that $\hat{\rho}_{ni} = \hat{\rho}_{in}$, and ι_n and η_i are importer- and exporter-effects, respectively. As the exporter effect is $\hat{\eta}_i = S_i - \theta ln\left(t_i\right)$ and the importer effect is $\hat{\iota}_n = -S_n$, we infer export costs as $ln\left(\hat{t}_n\right) = -\left(\hat{\iota}_n + \hat{\eta}_n\right)/\theta$. With the trade share data in Table 2, it is simple to estimate this regression, given an assumed value for trade's elasticity θ. Using the regional input-output data described in the previous section, we estimate internal and external trade costs between each of China's regions with each other and the rest of the world. We set the elasticity parameter to 4, in line with recent results by Simonovska and Waugh (2011), and leave a full discussion of this parameter to the model calibration in Section 3.7. We present these estimates in Table 4.[12] As with the symmetric trade cost estimate alone, these estimates of trade costs are unaffected by any aggregate trade imbalance. Before discussing the results, it is important to keep in mind that all costs are *relative to within-province trade costs*, since we normalized $\tau_{nn} = 1$. So, only results across columns within rows of Table 4 are comparable.

Some notable patterns emerge, though it is important to keep in mind that these trade costs are *relative to within-region* trade costs. The south coastal region faces import costs from the rest of the world of just over 70% in both 2002 and 90% in 2007, in contrast to the other regions of China that sees a drop in international import costs. The for the rest of the world in import from China also dramatically declines between 2002 and 2007, for all regions. The typical region, for example, faces more than 500% in export costs abroad but by 2007 this cost has declined to about 350%. The central region provinces of Shanxi, Henan, Anhui, Hubei, Hunan, and Jiangxi faced the highest costs to import from abroad. The region with the greatest cost of exporting to the world is the northwest.

[11] See Head and Mayer (2014) for details behind this and related gravity regressions.

[12] In the appendix, we explore two alternative methods of inferring trade cost asymmetries, both yield very similar results. First, if symmetric trade costs are log-linear with distance d_{ni}, then we can infer t_n from fixed effects of an alternative regression $ln\left(\pi_{ni}/\pi_{nn}\right) = \delta ln\left(d_{ni}\right) + \iota_n + \eta_i + \epsilon_{ni}$ in a similar way as with directionless pair-effects. Second, this same class of models imply $\tau_{ni} = \left(P_n/P_i\right)\left(\pi_{ni}/\pi_{ii}\right)^{-1/\theta}$. We lack spatial price indexes for tradable goods but do have them for all consumer goods, including housing, as a composite. We use those data in place of tradables prices to infer trade costs. Our key results do not depend on how we infer asymmetric trade costs.

Table 4: Bilateral Trade Costs, Tariff-Equivalents and the Relative Change

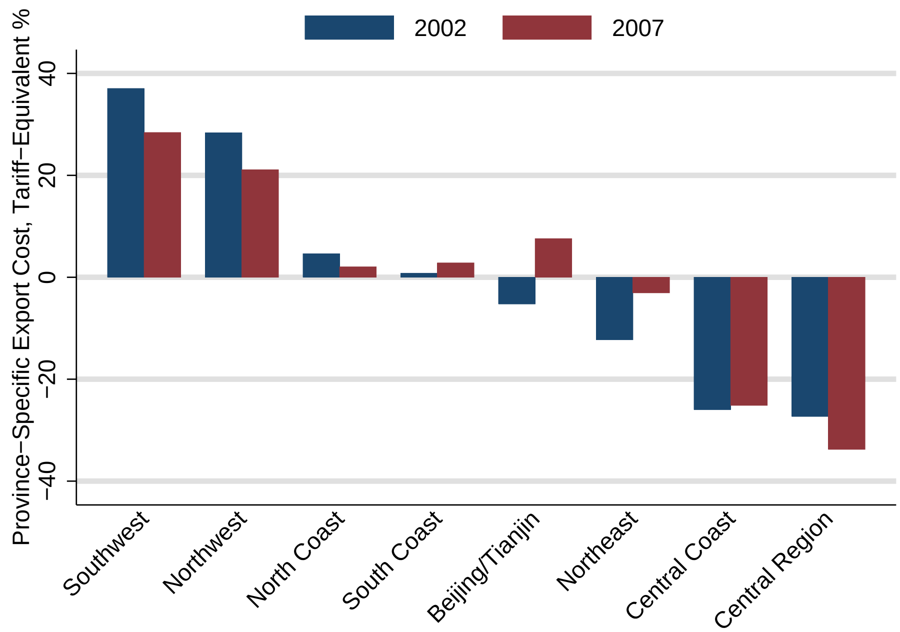
Importer	Exporter								
	North-east	Beijing Tianjin	North Coast	Central Coast	South Coast	Central Region	North-west	South-west	Abroad
Year 2002									
Northeast		169.2	206.7	240.6	237.2	195.5	244.6	296.8	566.1
Beijing/Tianjin	149.3		98.6	181.2	195.1	162.4	233.8	296.8	436.7
North Coast	157.2	79.9		133.1	191.8	110.4	203.3	299.9	483.7
Central Coast	303.7	260.0	229.5		191.8	121.8	271.6	322.0	407.7
South Coast	193.5	177.4	202.9	114.3		110.4	210.2	175.9	295.4
Central Region	256.7	242.1	202.9	125.9	191.8		259.6	321.6	777.2
Northwest	135.6	146.4	147.2	114.3	143.6	103.6		166.7	589.5
Southwest	154.0	174.3	205.3	127.9	102.9	123.6	149.8		566.1
Abroad	154.0	121.0	165.4	63.3	73.2	177.1	284.7	296.8	
Year 2007									
Northeast		137.4	155.4	160.6	153.9	127.7	182.5	223.6	381.9
Beijing/Tianjin	113.9		68.9	137.5	154.5	99.8	148.1	223.6	292.3
North Coast	142.6	78.0		130.8	159.1	66.9	134.7	216.9	365.1
Central Coast	237.5	241.4	214.6		159.1	86.5	205.1	269.7	310.8
South Coast	139.4	166.2	157.1	88.6		66.9	133.6	118.4	253.5
Central Region	233.3	224.5	157.1	110.8	159.1		190.9	250.8	532.4
Northwest	126.1	120.4	97.8	88.6	98.4	59.1		119.3	328.9
Southwest	144.3	171.1	151.9	115.5	74.9	80.9	106.9		381.9
Abroad	144.3	120.7	148.2	60.8	90.0	119.0	171.6	223.6	
Change in Trade Costs, 2002-2007, as $\tau_{ni}^{2007} / \tau_{ni}^{2002}$									
Northeast		0.882	0.833	0.765	0.753	0.770	0.820	0.815	0.723
Beijing/Tianjin	0.858		0.850	0.845	0.862	0.761	0.743	0.815	0.731
North Coast	0.943	0.990		0.990	0.888	0.793	0.774	0.793	0.797
Central Coast	0.836	0.948	0.955		0.888	0.841	0.821	0.876	0.809
South Coast	0.816	0.960	0.849	0.880		0.793	0.753	0.792	0.894
Central Region	0.934	0.948	0.849	0.933	0.888		0.809	0.832	0.721
Northwest	0.960	0.894	0.800	0.880	0.814	0.781		0.822	0.622
Southwest	0.962	0.988	0.825	0.946	0.862	0.809	0.828		0.723
Abroad	0.962	0.998	0.935	0.984	1.097	0.790	0.706	0.815	

Note: Displays our bilateral trade cost estimates from Section 4.2. The bottom panel displays the ratio of τ_{ni} in 2007 to its value in 2002. Tariffs are reported as $100(\tau_{ni} - 1)$. 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).

Within China, trade costs are also substantial and decreasing. In 2002, the average import cost across all regions was nearly 190%. By 2007 this cost fell below 150%. There is substantial variation in these costs across regions. Trade for the south coast to import from most other regions were in excess of 190% in 2002 and over 150% in 2007. The central region provinces also have large internal costs. These are also among the poorest regions in China. This is consistent with a systematic pattern for internal trade costs: poor regions face larger costs of exporting than richer regions. This is identical to the international results of Waugh (2010) and the within-country results of Tombe and Winter (2014). Overall, the typical region experienced declines in the cost of importing goods from other regions of China by 15% between 2002 and 2007. The typical cost to import goods from abroad declined by much more, about 25%. For exporting, the typical region experienced declines in trade costs of just under 15%, both internally and externally.

Finally, as discussed, all asymmetries in trade costs between trading pairs is due to province-specific export costs. We display the estimates of $ln\left(\hat{t}_n\right)$ for both 2002 and 2007 in Figure 5. As the overall level of export costs is undetermined, we express values relative to the mean across

Figure 5: 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 30 for a certain region implies it is 30 percent more costly to export from that region to any other, relative to the export costs for the average region.

all regions within each year. Overall, it is more costly for poor regions to export than rich regions – consistent with international evidence from Waugh (2010). There were also very few changes to the ranking across regions in trade cost asymmetries between 2002 and 2007. One exception, though, is Beijing and Tianjin, which experienced slightly larger than average export costs in 2007 compared to slightly lower than average costs in 2002 – though this does not imply export costs increased, we must emphasize only the ratio of export costs between regions matters for trade cost asymmetries.

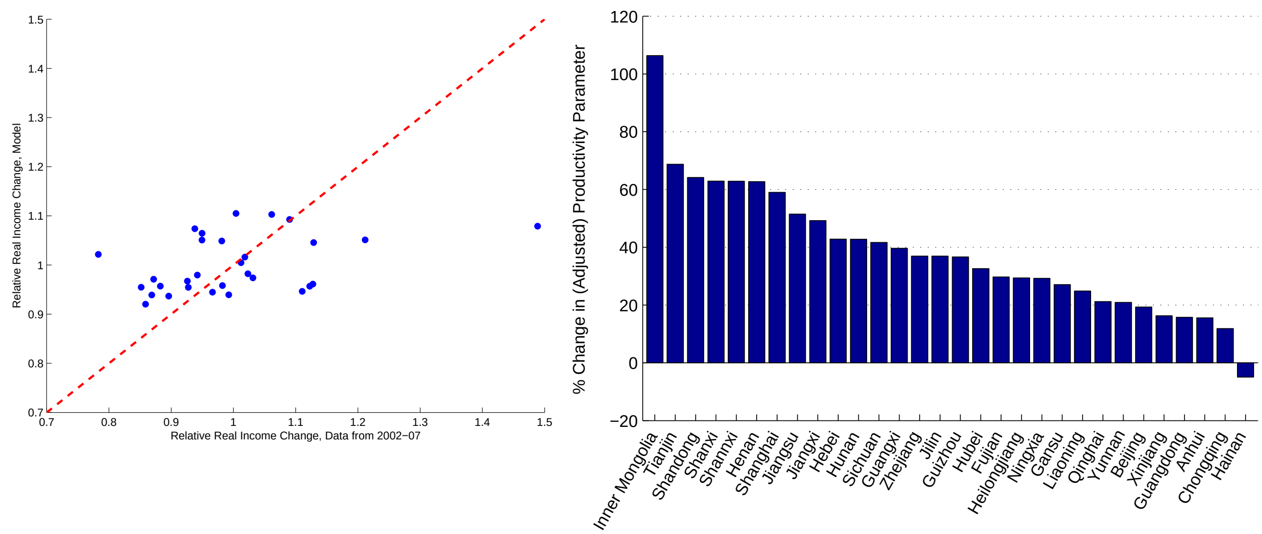
What is behind the the measured reduction in trade costs? As a first pass, consider isolating the portion of trade costs due to bilateral distance. With trade cost asymmetries $\tau_{ni} = t_{ni}t_i$, from equation 18 we have $\bar{\tau}_{ni} = t_{ni}\sqrt{t_i t_n}$. So, consider the following regression

$$ln(\bar{\tau}_{ni}) = \delta ln(d_{ni}) + \iota_n + \eta_i + \epsilon_{ni},$$

where d_{ni} is the geographic distance between region n and i, and ι_n and η_i are importer and exporter fixed-effects (to control for t_i and t_n). We include only regions within China for this regression. The results for 2002 imply a distance-elasticity $\hat{\delta} = 0.26$. For 2007, this elasticity falls to $\hat{\delta} = 0.22$. The contribution of distance to trade costs is therefore lower, perhaps due to infrastructure improvements within China. If all other factors remain unchanged, trade costs would have fallen by $d_{ni}^{-0.04}$ between region n and i. Overall, this averages 0.952 across all pairs, compared

Figure 6: Model Real Income and Required Productivity Changes

(a) Real Income Changes when $\hat{T}_n = 1$ (b) Required Change in $\hat{T}_n^{1/\theta}$



Notes: Compares the model-implied change in each province's real income $\hat{V}_n$ when underlying productivity is constant to real income changes measured in data. Both are expressed relative to the mean. In order for the model implies real income changes to match data, we require changes in underlying productivity draws $\hat{T}_n$. The implied productivity change in display in the right panel, adjusted as $\hat{T}_n^{1/\theta}$.

to an average $\tau_{ni}^{2007}/\tau_{ni}^{2002}$ (from Table 4) of 0.854. Though this is a rough approximation, perhaps one-third of the overall reduction in internal trade costs may therefore be due to lower distance costs.[13]

4.3 Underlying Productivity

Simulating both migration cost and trade cost reductions results in counterfactual changes in real incomes (per effective worker) across provinces. These changes, not surprisingly, do not match what we measure for $\hat{V}_n$ from data. We compare the model outcomes to data in Figure 6 (a). In the model, change in productivity (or within-region trade costs τ_{nn}) are captured by T_n. We calibrate changes in provincial the productivity parameter $\hat{T}_n$ such that, when migration and trade costs decline as measured, the resulting real income per effective worker changes match data.

The necessary values for $\hat{T}_n$ are displayed in Figure 6 (b). We rescale to $\hat{T}_n^{1/\theta}$ since this represents the model implied change in productivity if there was no trade (autarky) and no migration. Overall, there is substantial variation in $\hat{T}_n$ across provinces. From a high of nearly 40% for Inner Mongolia to a low of slightly negative for Hainan. The effect of these productivity changes can be simulated along side, or in addition to, the changes in trade and migration costs. It is to quantifying all of their effects that we now turn.

[13] A regression of our measured $\tau_{ni}^{2007}/\tau_{ni}^{2002}$ on $d_{ni}^{-0.04}$ yields a coefficient of 1 and an R^2 of 0.12 – suggesting 12% of the bilateral changes are accounted for by changes in distance costs.

5 Quantitative Analysis

We begin our quantitative analysis with a set of simple counterfactuals: exploring welfare and productivity changes without trade and without migration. These correspond to standard Gains from Trade experiments, where we ask by how much current welfare is relative to what it would be in autarky. Next, we conduct a series of counterfactual experiments to evaluate the consequences of China's measured changes in trade costs $\hat{\tau}_{ni}$ and migration costs $\hat{\mu}_{ni}$ and generally large increases in underlying productivity $\hat{T}_n$. We examine the effect of changes in migration costs and changes in trade and migration cost separately and together. We then examine the effect of productivity changes, and how they potentially interact with changes in trade and migration costs. We conclude with a discussion of the spatial distribution of provincial real income changes. As we measure the changes between 2000/02 - 2005/07, consider these exploring the underlying causes of China's trade, migration, regional incomes, and aggregate welfare changes over that period (in terms of $\hat{\tau}_{ni}$, $\hat{\mu}_{ni}$, and $\hat{T}_n$).

5.1 Gains from Trade and Migration

Examining a counterfactual where there is no trade or migration is straightforward. Consider a special case of our model model without separate internal regions or migration. Aggregate welfare changes are $\hat{W} = \hat{\pi}_{nn}^{-\alpha/\theta(\beta+\eta)}$. In autarky, $\pi_{nn} = 1$ so the relative change in the home share in a counterfactual of autarky is $\hat{\pi}_{nn} = 1/\pi_{nn}$ – or, from autarky to the current level of trade, $\hat{\pi}_{nn} = \pi_{nn}$. So, given China's aggregate home share was 0.927 in the initial equilibrium, the standard gains from international trade are $\hat{W} = 1.042$. To simulating the gains from international trade in our framework is more complex. Imagine a counterfactual trade cost where $\tau_{ni} = \infty$ is either n or i was the world, and $\tau_{ni} = 1$ otherwise. This change will eliminate all international trade between each province and the world. The inverse of the change in aggregate welfare is then the gains from the observed initial level of international trade. We find gains of 3.6% – smaller than the 4.2% an aggregated model would suggest. It turns out, intuitively, that internal trade dampens the gains from international trade. That is, losing access to international markets is less costly for each region because of substitute suppliers from a number of other provinces within China. Does internal migration interact with these gains from international trade? We can repeat the above experiment holding the spatial distribution of workers fixed. In this case, increasing international trade costs to infinity and leaving them unchanged everywhere else suggests gains from international trade of 3.3%. This suggests *internal migration amplifies the gains from international trade* by roughly 10%. Spatially, gains are also not evenly distributed. Rich regions gain substantially more than poor regions – on the order of 10%.

Next, consider the gains from all trade – both internal and international. This involves simulating the model where $\tau_{ni} = \infty$ if $n \neq i$ and $\tau_{ni} = 1$ otherwise. Essentially, this examines every province moving to autarky. Consider first consider this counterfactual holding fixed the spatial distribution of labour. In this case, $\hat{H}_n = 1$ for all n and $\hat{\pi}_{nn} = \pi_{nn}$. From our earlier expression for aggregate welfare changes,

$$\hat{W} = \sum_{n=1}^{N} \omega_n \pi_{nn}^{\frac{\alpha}{\theta(\beta+\eta)}} = 1.163.$$

So, the gains from trade in our model is 16.3%. Individual regions differ in their gains, however. Rich regions gain substantially more, around 30% compared to only 10% for poor regions. Allowing a migration response, where $\hat{H}_n$ can endogenously respond to the change in trade costs, little changes. We find the gains in this case are only slightly higher, at 16.5%.

Finally, we examine the gains from the observed level of initial migration relative to the counterfactual where all migrants remained in their home province. In this case, $\hat{H}_n = H_n/L_n^0$ and $\hat{m}_{nn} = m_{nn}$ and trade share changes $\hat{\pi}_{nn}$ endogenously respond. The gains in this case are only 1.1% in aggregate. The initial level of migration is fairly small – only roughly 4% of the labour force migrates across provincial boundaries – so the resulting small aggregate gains from migration is not surprising. Even this small level of migration, though, dampens regional income differences. Poor regions gain more (about 2%) than rich (who lose about 3%). Without migration, the 90/10 ratio of real GDP per worker is 4.08 compared to the 3.38 in the initial equilibrium. Internal trade as a share of GDP changes little, and the external trade to GDP ratio declines by 0.33 percentage points. So, very little of China's initial international trade is attributable to the initial level of migration.

5.2 The Effect of Lower Trade Costs

Moving beyond the static gains from the initial levels of migration and trade, consider the consequences of lowering trade and migration costs between the 2000/02 and 2005/07 periods by the changes we measured. We resolve the model using $\hat{\tau}_{ni}$ from section 4.2, and hold migration costs and regional productivity fixed ($\hat{\mu}_{ni} = \hat{T}_n = 1$ for all n and i).

Table 5 displays the change in international trade flows, aggregate welfare, and overall inter-provincial migration flows for each of our counterfactuals. Lower internal trade costs, not surprisingly, lower the amount of international trade as households and firms reorient their purchase decisions towards domestic suppliers. The magnitudes are substantial. Our estimates imply that the the improvements in inter-provincial trade subtracted over 8% from international trade flows and lowered the international trade to GDP ratio by nearly three percentage points. Lower external trade costs reveals a different pattern. With improved international trade, the total volume of trade increased by nearly 18 percentage points of GDP. The total volume increased by nearly 60%.

In terms of migration, improved internal trade costs actually resulted in *fewer* workers living outside their home province. The total stock of migrants declined by nearly 2% (equivalent to approximately 0.5 million workers). Intuitively, internal trade costs declining disproportionately lower goods prices in poor, interior regions. This increase in real income means fewer workers, who were living in other provinces, were willing to continue to do so. The stock of migrants therefore declined. On the other hand, the decline in external costs disproportionately benefit richer coastal regions, leading more workers to locate there. The change in nominal income is

Table 5: Counterfactual Aggregate Outcomes

Measured Cost	p.p. Change in Trade/GDP Ratio		Migrant	Per-Capita Income	Aggregate Outcomes	
Reduction of	Internal	External	Stock	Variation	Real GDP	Welfare
Internal Trade	38.7	-2.7	-1.8%	-3.6%	7.9%	7.3%
External Trade	-3.1	17.8	0.8%	2.1%	3.0%	2.5%
All Trade	34.1	13.7	-0.9%	-1.5%	10.8%	9.6%
Migration	0.0	0.0	37.1%	-8.9%	0.9%	0.4%
Internal Reform	38.6	-2.6	33.1%	-11.9%	8.8%	7.7%
Everything	34.1	13.8	34.2%	-10.2%	11.7%	10.1%

Notes: Displays aggregate response to various counterfactuals. Trade costs and migration costs are reduced by the amount we measure in the text. The change in trade's share of GDP is displayed in terms of percentage point changes. 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.

largely similar across provinces, so this effect is driven by lower goods prices in these coastal regions.

The change in income, goods and land prices, and worker's location decision all have implications for aggregate welfare. We report the change in welfare in the last column of Table 5. In response to lower internal costs, aggregate welfare dramatically increased by over 7.3%. In contrast, external trade cost reductions resulted in a much small gain of only 2.5%. Internal reforms appear to be significantly more important for aggregate outcomes. This follows from the fact that most provinces allocated a larger fraction of their income to goods from other Chinese provinces than goods from abroad.

5.3 Lower Migration Costs

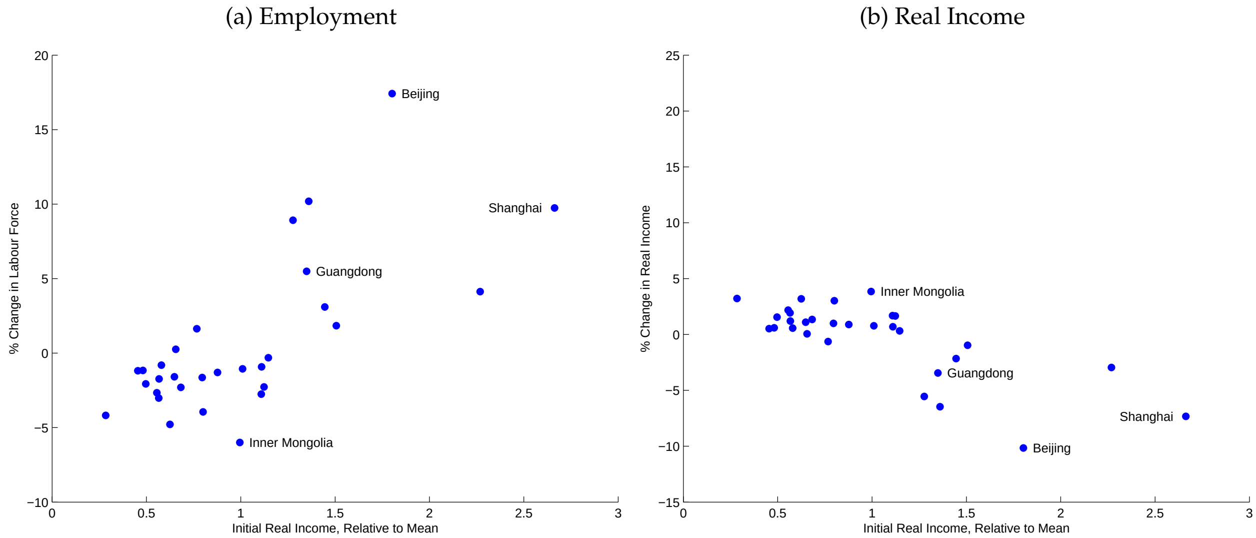
Trade liberalization accounts for only limited inter-provincial migration. Not surprisingly, lower migration costs allow substantially more workers to live outside their home province. As before, we simulate the effect of lower migration costs and report the aggregate effects in Table 5.

The number of inter-provincial migrants increases by over 37% – equivalent to over 10 million additional workers living outside their home province. Migrants primarily move towards rich regions. In fact, Beijing experiences a 17% increase in its labour force and Shanghai and Guangdong both experience a 10% increase. In contrast, Inner Mongolia's labour force declines by 6%. There is a strong positive correlation between a province's initial real income and its labour force change $\hat{L}_n$ in response to lower migration costs.[14] We plot each province's change in Figure 7. The effect of large inflows to rich regions also lowers their real incomes – wages fall and land prices rise in response to larger employment. Overall regional variation in real income declines by nearly 9%.

The effect of lower migration costs on aggregate trade flows and welfare, however, is muted.

[14] We measure differences in real income here on a *per-capita* basis, calculated as $\hat{H}_n \hat{V}_n / \hat{L}_n$. For the most part, $\hat{H}_n$ and $\hat{L}_n$ are very similar in values so all results hold when expressed in per effective worker terms $\hat{V}_n$.

Figure 7: Employment and Real Income Response to Lower Migration Costs



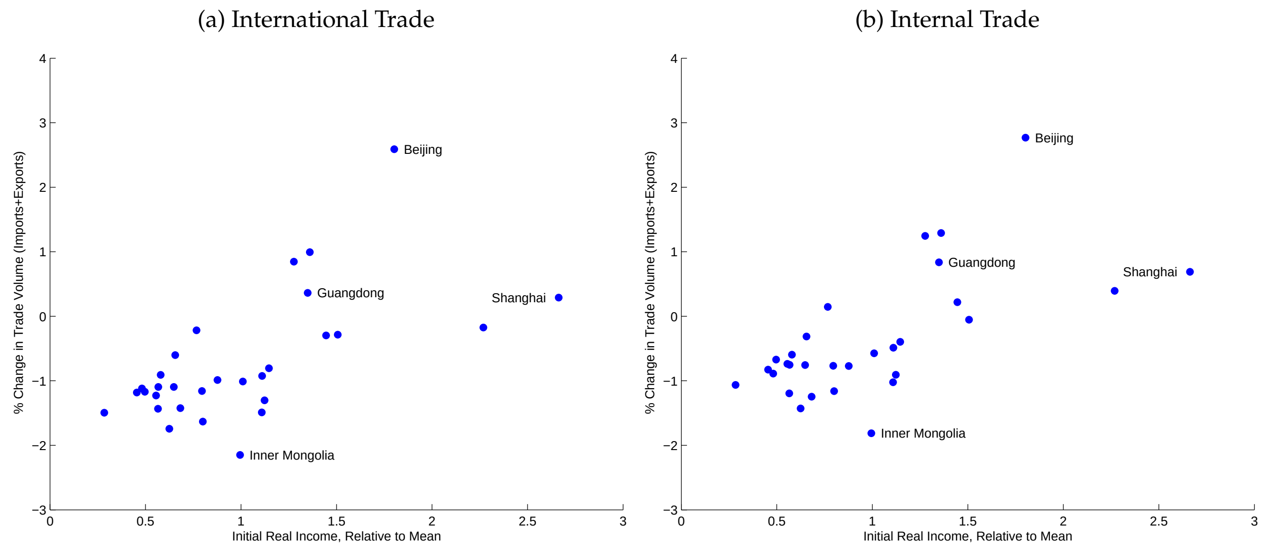
Notes: Displays the percentage change in employment $\hat{L}_n$ and real income per capita $\hat{H}_n \hat{V}_n / \hat{L}_n$ by province in response to lower inter-provincial migration costs.

International trade volumes increase by approximately 0.12% and internal trade volumes increase by only 0.02%. The trade to GDP ratios therefore barely move. Welfare is also largely unresponsive in aggregate, with an increase of only 0.4%. Differences between these measures is because welfare accounts for migration costs incurred and worker productivity differences over locations. Global welfare, something the model captures through $\hat{V}_{N+1}$ is unchanged.

While aggregate trade is largely unresponsive, there are substantial differences between individual provinces. In Figure 8 we plot the percentage change in each province's trade volumes, both internally and internationally. While the two panels look identical, they do differ slightly. Initially higher income (coastal) regions see their trade increase. For some regions, such as Beijing, the magnitudes are larger – roughly 3% increase in international trade, but a half-point decline in trade to GDP. Lower income (interior) regions see their trade volumes decrease. Inner Mongolia, for example, experiences a large reduction in its trade. These patterns are similar for exports and imports, internally and internationally.

What drives the spatial variation in trade's response to migration cost changes? Wages and decline in rich regions while land prices increase. As wage changes dominate land price changes, goods prices decline and therefore these coastal regions become more attractive to buyers, both abroad and in other regions. Similarly, rich regions purchase a greater share of goods from their own producers, and consequently less other regions or abroad. This does not mean imports by rich regions declines, however. Total expenditures also rise in these regions, as there are substantially more workers, so import volumes will rise despite the higher home shares. So, while aggregate trade is does not change, the spatial pattern of trade does.

Figure 8: Trade Volume Response to Lower Migration Costs



Notes: Displays the percentage change in trade volumes, both internationally and internally, for each provinces resulting from lower migration costs. Aggregate trade changes little, but there is substantial variation across provinces. Coastal regions trade more more as a result of lower internal migration costs; interior regions trade less.

5.4 Lower Trade and Migration Costs

Simulating both trade and migration cost reductions together reveals the two reinforce each other's effect on migration and welfare. With easier migration flows, lower trade costs have larger welfare gains. The number of migrants, though, is slightly lower than the case when migration costs alone decline. Welfare gains are 10.1%, which is *slightly* more than the combined welfare gains from trade cost and migration cost reductions performed separately. Finally, the increase in international trade flows is very similar to the trade liberalization experiment alone, which is not surprising as migration leads to little international trade response.

At the province level, we report the change in employment and trade flows over all counterfactual experiments in Figures 10 and 11. The destination for migrants are consistently the coastal provinces, such as Shanghai, Tianjin, Beijing, and Guangdong. The source regions are from the interior provinces, such as Anhui, Sichuan, Hunan, among others. Overall employment for destination provinces increases more for external liberalizations than internal. For Shanghai, the change due to external trade cost reductions is actually larger than for migration cost reductions. The last panel of Figure 10 also displays an extremely close correlation to the data. Our measured reduction of trade and migration costs not only capture most of the aggregate number of migrants but also the spatial distribution of source and destination provinces.

The province level trade flow response to the various experiments is in line with the aggregate results. Little change results anywhere in terms of international trade flows when migration costs decline. Internal trade cost reductions also generate less international trade, mainly due to trade declines in a few key provinces; namely, Guangdong, Shanghai, and Tianjin. External trade cost

Table 6: Counterfactual Aggregate Outcomes, With Changes in Productivity $\hat{T}_n$

Change in Productivity and ...	p.p. Change in Trade/GDP Ratio: Internal	External	Migrant Stock	Per-Capita Income Variation	Aggregate Outcomes: Real GDP	Welfare	Marginal Welfare Change
Productivity Only	-1.0	-4.6	-9.3%	11.5%	47.2%	40.3%	–
Internal Trade	36.8	-6.9	-12.3%	6.2%	58.5%	50.2%	7.1%
External Trade	-3.8	11.5	-8.3%	13.1%	51.1%	43.3%	2.2%
All Trade	32.9	7.9	-11.2%	8.0%	62.3%	53.1%	9.2%
Migration	-1.0	-4.6	22.4%	3.1%	48.2%	40.8%	0.4%
Internal Reform	36.8	-6.8	17.2%	-1.5%	59.6%	50.7%	7.5%
Everything	32.8	7.9	18.5%	-0.1%	63.4%	53.7%	9.5%
Data (2002-07)	17	12	18.5%	-0.1%	53.2%	–	–

Notes: Displays aggregate response to various counterfactuals, as in section 5 and Table 5, but allows province-specific technological change such that real income changes in the "Everything" experiment match data. The final column – marginal welfare changes – give the change in welfare in addition to the productivity-only welfare change; these values are directly comparable to Table 5.

reductions, on the other hand, drive very large increases in trade flows, especially for coastal regions.

5.5 Changes in Productivity

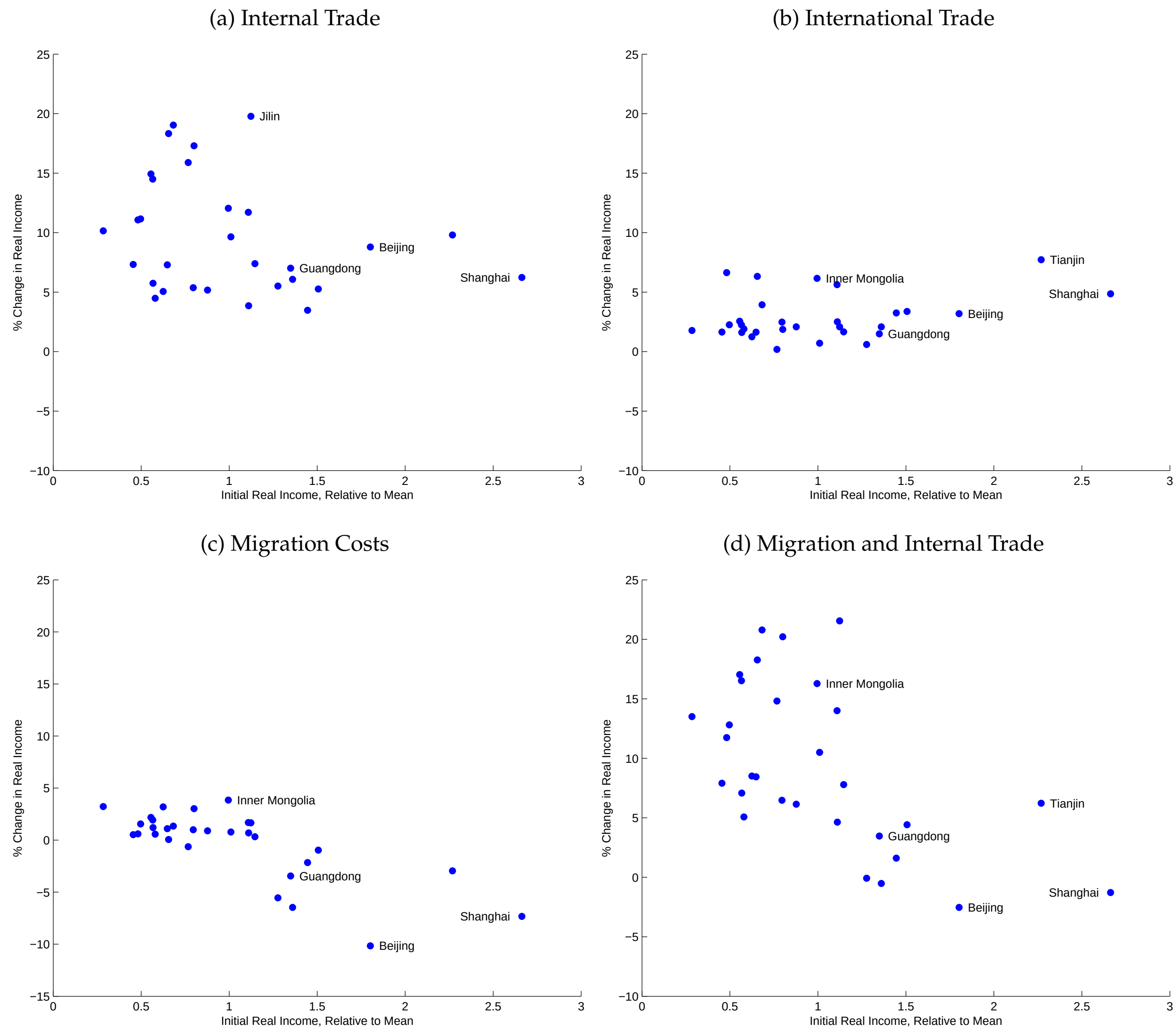
We repeat our main quantitative exercises and display the results in Table 6. The first row of this table is distinct, and provides the effect of our calibrated $\hat{T}_n$ alone. Clearly, welfare is substantially improved from the large productivity increases. More interestingly, trade declines as a share of GDP, fewer migrants live outside their home region, though income variation increases. The marginal effect of each subsequent experiment – lower trade costs and lower migration costs – are similar to our baseline results in Table 5 with one exception. The change in the stock of migrants from lower migration costs is substantially lower than our baseline, and much closer to the level actually observed.

5.6 Discussion: Regional Income Differences

In this section, we (briefly) discuss real income changes by provinces to illuminate the effect of various reforms on regional income differences. As before, we measure these differences on a *per-capita* basis, calculated as $\hat{H}_n \hat{V}_n / \hat{L}_n$.

Figure 9 plots, using a common scale, the change in real incomes under four key changes in costs to: (1) internal trade cost; (2) external trade cost; (3) migration; and (4) internal trade and migration (what we call domestic reforms). Internal costs clearly lower differences in real income, as poor provinces disproportionately gain. External trade costs, by contrast, have a fairly uniform effect across provinces. Tianjin and Shanghai do gain more than most, so overall regional income differences rise under this reform. For the most part, though, there is no systematic relationship

Figure 9: Real Income Responses to Various Counterfactuals



Notes: Displays the percentage change in real incomes per capita for each provinces resulting from selected counterfactual. From the model, per capita income changes are $\hat{H}_n \hat{V}_n / \hat{L}_n$.

between initial real income and the real income gains from changes in external costs. Next, as previously discussed, migration costs lower real income differences but, when coupled with internal trade cost reductions there is an even stronger relationship. Here, through domestic reforms, poor provinces gain substantially more than rich provinces. Indeed, some rich provinces – Bejiing especially – actually experience slight *reductions* in real income from the inflow of workers. Our results suggest internal liberalization is much more important than external liberalization as a source of aggregate welfare gains and improvements in regional income inequality.

6 Robustness

Our quantitative analysis found (1) internal reforms significantly more important for welfare than external trade liberalization, (2) internal reforms lower regional income differences while external trade liberalization increases them, (3) lower migration costs (rather than lower trade costs) drive most migration, and (4) lower migration costs result in larger trade flows from rich coastal regions but small trade flows from interior regions. In this section, we explore the robustness of these general results.

Alternative Migration Elasticities

Our results are robust to alternative values for κ. In the appendix, we demonstrate that our measure of migration cost changes is largely robust to alternative (higher) values of κ. We present alternative results in Table 12 for our main aggregate outcomes of each counterfactual experiment when $\kappa = 5$ and $\kappa = 10$. Only one aspect of our quantitative analysis depends on the value of κ: the sensitivity of migration to changes in trade and migration costs. This is intuitive. The parameter κ governs the real income elasticity of migration flows. In the extreme case of $\kappa = 10$, we find the stock of migrants more than doubles in response to lower migration costs (over 30 million more inter-provincial migrants). The trade flow, income variation, GDP, and welfare consequences of all our main exercises are robust across a wide range of values for κ. Our main results are therefore robust.

Worker Heterogeneity in Location Preferences

Workers differ in their productivity across each other and across provinces. Our main model is also equivalent to interpreting z's as worker heterogeneity in migration costs, relative to some common average migration cost μ_{ni}. Instead, interpret μ_{ni} as the only real resource cost of migrating between provinces and let z's be pure preference differences across workers in terms of their preferred location. The model changes little, except $h_{ni} = 1$ and therefore the stock of effective labour is $H_n = \sum_{i=1}^{N} \mu_{in} m_{in} L_i^0$. The migration equation for m_{ni} is unchanged. We solve for the initial V_n in the same way, but using $(H_n V_n)^{data} = V_n \sum_{i=1}^{N} \mu_{in} m_{in} L_i^0$ and equation 17 to replace μ_{in}.

We display the results of our main counterfactuals under this alternative formulation in the second panel of Table 15. All of the main conclusions are robust, with the notable exception of a decline in real GDP when migration costs fall – though the welfare change is similar. This difference is simply because higher average z's realized by migrants no longer contribute to output. Effective labour previously increased with the z's; now, this is simply in the minds of migrants (a welfare gain, but not an productivity gain). Morevore, more migrants increases the total share of the labour force incurring μ_{ni}, and therefore the aggregate labour supply is much lower (by 1.5%). This was true before, but the improved z's compensate (aggregate effective labour supply in the baseline model falls by only 0.17%).

Finally, we explore the case if all migration costs and productivity differences are in worker preferences (both μ_{ni} and z). In this case, effective labour and employment are equivalent $H_n = L_n$ and the initial real income V_n matches real income per capita from data. The results of our main counterfactuals are in the final panel of Table 15. In this case, lower migration costs increase aggregate real GDP by nearly 2% (as there are no longer real resource costs of migration, this is nor surprising). Aggregate welfare, however, still only modestly increases. The other outcomes do not substantially change relative to out baseline model.

Trade Cost Asymmetries From Gravity Model

Next, we ensure our measure of trade cost changes does not depend on the way we infer trade cost asymmetries. We do this in two ways. First, to capture symmetric trade costs, we use distance (between population-weighted geographic centroids) instead of the directionless-pair fixed-effect. That is, we modify the regression from equation 19 to

$$ln\left(\frac{\pi_{ni}}{\pi_{nn}}\right) = \delta ln(d_{ni}) + \iota_n + \eta_i + \epsilon_{ni},$$

where d_{ij} is the distance between region n and i. Our estimate of $\hat{\delta} = -1.04$, consistent with existing estimates of the distance-elasticity of trade from the vast gravity literature. We then infer exporter-specific trade costs as before: $ln\left(\hat{t}_n\right) = -\left(\hat{\iota}_n + \hat{\eta}_n\right)/\theta$. The second way of ensuring our results do not depend on how we infer asymmetries is to use the unadjusted Head-Ries index $\bar{\tau}_{ni} = \left(\frac{\pi_{nn}\pi_{ii}}{\pi_{ni}\pi_{in}}\right)^{1/2\theta}$. With these alternatives, we repeat our quantitative analysis.

These alternative estimates imply slightly different relative changes in bilateral trade costs between China's regions with each other and with the world. We display these alternative measures in Table 13. Using these alternative estimates in our quantitative exercises results in only very small changes in aggregate results. We display these alternative results in Table 14. We conclude our method of inferring trade cost asymmetries does not drive our results.

Migrant Remittances

Migrants may send a portion of their labour income to relatives in their home province. We have no data on how prevalent this behaviour is or how large such remittances are, and only limited research on the question exists. Murphy (2006) provides a summary of survey data. Though there is no systematic measure, it appears that many migrants do remit. Zhu, Wu, Peng and Sheng (2014), for example, survey a large pool of migrants and find half of those with children remit. Of those, approximately one-third of income is remitted. In our data, only one-quarter of inter-provincial migrants have children, so remittances may not be a large cause of concern but we explore whether our results are sensitive to migrant remittances in any case.

In Appendix B, we describe in detail how the model changes if migrants remit a given (exogenous) share of nominal income to households back in their home provinces. Remittances are received as a wage subsidy. We explore a range of remittance rates – from 10-50% – and find none of our results change significantly. Our baseline model without remittances over-estimates migration costs, as any social norm to remit that limits migration flows will be captured by the migration cost parameter μ_{ni}. While a model with remittances results in lower migration costs, they are not substantially so, and the measured changes between 2000 and 2005 are similar to our main results. We conclude our analysis is robust to migrant remittances.

7 Conclusion

There is a widely held belief that China's rapid GDP growth since 2001 was a result of export expansion supported by the large increase in the supply of cheap migrant workers. However, this prominent role of international trade in generating GDP growth is not consistent with the prediction of many standard trade models. Applying the sufficient statistics approach suggested by Arkolakis et al. (2012) to China, the impact of international trade on GDP growth since 2001 is almost negligible. One possibility for the startling result is that the standard trade models does not take into account frictions in both internal trade and fact mobility, and one may expect that with the frictions the gains of trade maybe larger through the reallocation of labour and therefore reducing misallocation. In this paper we develop a general equilibrium model of internal-external trade with migration that explicitly take into account these frictions. The model is highly tractable and can be easily implemented for quantitative analysis. It also allows one to measure the magnitude of trade and migration costs. We apply the model to China and quantify the impacts of trade liberalization and migration on aggregate welfare and regional income differences. We find that, even with the frictions, the impact of international trade liberalization of China's growth is still very modest. In contrast, domestic reforms are substantially more important – they result in both more significant aggregate GDP growth and lower regional income differences.

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Supplementary Tables and Figures

Table 7: Summary Data for China's Provinces, 2002

Province	Employment Share	Home Bias	International Export Share of Total Production	Relative Real Income	Ratio of Net Three Year Migration to 2005 Employment
Anhui	0.053	0.619	0.024	0.56	-8.32%
Beijing	0.013	0.661	0.065	1.82	17.55%
Chongqing	0.026	0.545	0.020	0.72	-5.31%
Fujian	0.027	0.807	0.118	1.28	5.62%
Gansu	0.020	0.776	0.039	0.48	-1.56%
Guangdong	0.062	0.647	0.239	1.35	14.14%
Guangxi	0.040	0.694	0.027	0.50	-4.04%
Guizhou	0.033	0.718	0.017	0.29	-5.48%
Hainan	0.005	0.624	0.031	0.74	0.07%
Hebei	0.053	0.718	0.023	1.01	-1.10%
Heilongjiang	0.026	0.797	0.026	1.15	-2.58%
Henan	0.087	0.875	0.013	0.63	-4.33%
Hubei	0.039	0.857	0.016	0.88	-5.15%
Hunan	0.054	0.849	0.016	0.57	-5.25%
Inner Mongolia	0.016	0.775	0.020	1.00	3.56%
Jiangsu	0.055	0.802	0.100	1.45	-6.61%
Jiangxi	0.031	0.790	0.015	0.65	-1.21%
Jilin	0.017	0.554	0.025	1.13	0.73%
Liaoning	0.029	0.827	0.063	1.51	0.03%
Ningxia	0.004	0.633	0.014	0.68	-0.12%
Qinghai	0.004	0.640	0.038	0.66	0.71%
Shandong	0.075	0.830	0.060	1.11	-0.35%
Shanghai	0.012	0.645	0.179	2.67	23.06%
Shaanxi	0.029	0.758	0.001	0.57	-1.69%
Shanxi	0.022	0.858	0.036	0.80	-0.34%
Sichuan	0.069	0.881	0.020	0.58	-5.22%
Tianjin	0.006	0.552	0.153	2.28	10.51%
Xinjiang	0.011	0.757	0.025	1.11	2.09%
Yunnan	0.037	0.807	0.017	0.46	-0.34%
Zhejiang	0.045	0.743	0.094	1.37	11.89%

Notes: 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). Net migration as a fraction of 2005 employment is measured as the difference between inflows and outflows of migrants between 2002 and 2005, as captured in the 2005 census. Spatial price levels for each province are from Brandt and Holz (2006), updated using provincial CPI data.

Table 8: Employment by Industry, 2000 and 2005

Industry	Total Employment Levels 2000	Total Employment Levels 2005	% Change
Agriculture	430,456,800	411,558,525	-4.39%
Mining and Quarrying	6,982,100	10,558,129	51.22%
Manufacturing	80,021,800	89,041,261	11.27%
Utilities	6,799,600	5,073,626	-25.38%
Construction	15,984,100	23,608,993	47.70%
Geological Prospecting and Water Management	2,962,100	795,769	-73.13%
Transport, Storage, Post, and Telecom Services	15,934,500	21,163,253	32.81%
Wholesale and Retail Trade, and Catering	37,912,900	59,374,065	56.61%
Finance and Insurance	8,578,200	3,772,039	-56.03%
Real Estate	3,928,300	2,352,179	-40.12%
Social Services	13,374,900	18,522,857	38.49%
Healthcare, Sports, and Social Welfare	1,461,800	7,980,420	445.93%
Education, Culture and Arts, Radio, Film, and TV	7,896,300	17,546,845	122.22%
Scientific Research and Polytechnic Services	333,700	1,443,059	332.44%
Government, Party, Etc...	17,059,500	17,211,324	0.89%
Other	18,829,900	9,775,045	-48.09%
Total	668,516,500	699,777,389	
From Holz (2006):	720,850,000	758,250,000	
Share the census captures:	92.7%	92.3%	

Table 9: Employment by Industry and Region, 2000 and 2005

	Region			
	East	Middle	Northeast	West
Employment in 2000				
Agriculture	144,003,200	140,142,100	29,185,800	117,125,700
Mining and Quarrying	2,083,300	2,431,800	1,129,000	1,338,000
Manufacturing	51,115,200	13,817,200	6,136,900	8,952,500
Utilities	3,893,400	1,485,700	557,200	863,300
Construction	8,467,300	3,595,200	1,257,200	2,664,400
Geological Prospecting and Water Management	1,771,100	573,400	215,700	401,900
Transport, Storage, Post, and Telecom Services	6,827,800	4,218,500	2,036,900	2,851,300
Wholesale and Retail Trade, and Catering	18,647,600	9,016,500	3,800,200	6,448,600
Finance and Insurance	4,132,400	1,988,900	750,100	1,706,800
Real Estate	1,720,400	1,037,500	484,200	686,200
Social Services	6,794,800	2,881,000	1,535,800	2,163,300
Healthcare, Sports, and Social Welfare	807,200	252,600	104,500	297,500
Education, Culture and Arts, Radio, Film, and TV	3,357,000	2,147,300	899,500	1,492,500
Scientific Research and Polytechnic Services	160,900	76,000	39,500	57,300
Government, Party, Etc...	6,908,800	4,847,600	1,726,300	3,576,800
Other	8,009,300	5,237,500	1,974,000	3,609,100
Employment in 2005				
Agriculture	130,204,739	133,589,796	30,133,229	117,630,761
Mining and Quarrying	3,085,432	3,742,953	1,480,847	2,248,897
Manufacturing	61,129,267	14,887,977	5,297,513	7,726,503
Utilities	2,146,520	1,464,309	602,199	860,599
Construction	12,946,664	5,796,478	1,396,542	3,469,309
Geological Prospecting and Water Management	271,357	263,988	81,741	178,683
Transport, Storage, Post, and Telecom Services	9,422,982	6,110,891	2,297,478	3,331,903
Wholesale and Retail Trade, and Catering	29,733,735	14,747,624	5,329,514	9,563,192
Finance and Insurance	1,765,619	937,813	457,570	611,037
Real Estate	1,505,858	342,388	198,563	305,369
Social Services	9,197,180	4,424,297	1,954,916	2,946,464
Healthcare, Sports, and Social Welfare	3,364,870	2,274,286	816,584	1,524,680
Education, Culture and Arts, Radio, Film, and TV	7,189,365	5,054,902	1,700,249	3,602,329
Scientific Research and Polytechnic Services	836,281	238,903	142,294	225,580
Government, Party, Etc...	7,078,403	5,054,844	1,731,502	3,346,576
Other	5,292,035	1,991,362	1,239,084	1,252,564

Table 10: Inter-Provincial Migrants by Industry and Region, 2000 and 2005

	Region			
	East	Middle	Northeast	West
Migrants in 2005 by Industry of Employment				
Agriculture	818,426	144,271	89,291	306,833
Mining and Quarrying	138,285	158,778	24,590	85,093
Manufacturing	15,345,897	309,910	175,601	253,768
Utilities	74,398	11,134	1,891	18,452
Construction	2,475,960	236,613	74,876	261,446
Geological Prospecting and Water Management	13,148	1,340	645	609
Transport, Storage, Post, and Telecom Services	697,468	54,739	19,799	63,147
Wholesale and Retail Trade, and Catering	4,017,347	417,291	225,842	537,288
Finance and Insurance	32,864	2,672	994	3,525
Real Estate	220,790	14,524	6,199	9,151
Social Services	1,651,331	107,123	63,756	141,817
Healthcare, Sports, and Social Welfare	105,207	10,460	3,326	6,161
Education, Culture and Arts, Radio, Film, and TV	181,173	19,280	9,769	16,687
Scientific Research and Polytechnic Services	58,182	3,929	393	2,651
Government, Party, Etc...	84,099	4,609	2,076	8,108
Other	695,408	32,332	22,596	33,790
Migrants as Fraction of Employment Growth				
Agriculture	-5.93%	-2.20%	9.42%	**60.75%**
Mining and Quarrying	13.80%	12.11%	6.99%	9.34%
Manufacturing	**153.24%**	28.94%	-20.92%	-20.70%
Utilities	-4.26%	-52.05%	4.20%	-683.16%
Construction	**55.27%**	10.75%	53.74%	32.48%
Geological Prospecting and Water Management	-0.88%	-0.43%	-0.48%	-0.27%
Transport, Storage, Post, and Telecom Services	**26.88%**	2.89%	7.60%	13.14%
Wholesale and Retail Trade, and Catering	**36.24%**	7.28%	14.77%	17.25%
Finance and Insurance	-1.39%	-0.25%	-0.34%	-0.32%
Real Estate	-102.91%	-2.09%	-2.17%	-2.40%
Social Services	**68.74%**	6.94%	15.21%	18.11%
Healthcare, Sports, and Social Welfare	4.11%	0.52%	0.47%	0.50%
Education, Culture and Arts, Radio, Film, and TV	4.73%	0.66%	1.22%	0.79%
Scientific Research and Polytechnic Services	8.61%	2.41%	0.38%	1.58%
Government, Party, Etc...	**49.59%**	2.22%	39.91%	-3.52%
Other	-25.59%	-1.00%	-3.07%	-1.43%

Table 11: Region Specific Calibrated Values

Province	Initial Total Expenditures X_n	Hukou Number (M) L_n^0	Real Income per Effective Worker V_n	Stock of Effective Workers H_n
Anhui	0.026	36.8	0.38	49.8
Beijing	0.037	6.5	1.42	10.2
Chongqing	0.013	17.2	0.55	23.7
Fujian	0.034	16.3	0.93	23.6
Gansu	0.008	12.7	0.33	18.0
Guangdong	0.115	27.6	1.18	45.5
Guangxi	0.015	27.5	0.34	37.6
Guizhou	0.007	21.8	0.19	30.6
Hainan	0.004	3.3	0.54	4.9
Hebei	0.055	34.0	0.71	48.2
Heilongjiang	0.029	16.7	0.80	23.3
Henan	0.048	57.1	0.44	79.3
Hubei	0.029	26.1	0.61	35.7
Hunan	0.030	37.9	0.39	50.9
Inner Mongolia	0.013	10.0	0.70	14.4
Jiangsu	0.103	34.3	1.04	48.8
Jiangxi	0.015	22.2	0.44	29.1
Jilin	0.018	11.1	0.79	15.6
Liaoning	0.059	18.1	1.07	25.9
Ningxia	0.002	2.8	0.48	4.0
Qinghai	0.002	2.5	0.46	3.5
Shandong	0.091	47.5	0.78	67.4
Shanghai	0.054	5.6	2.31	8.6
Shaanxi	0.015	19.1	0.39	26.9
Shanxi	0.019	14.0	0.56	20.1
Sichuan	0.030	48.1	0.40	64.6
Tianjin	0.021	3.7	1.68	5.4
Xinjiang	0.011	6.2	0.82	9.4
Yunnan	0.013	22.9	0.32	33.7
Zhejiang	0.088	26.8	1.00	38.7

Notes: Lists the values for the region-specific initial values. Some are calibrated while others are directly observables from data. See section 3.7 for details.

Table 12: Counterfactual Outcomes, Alternative κ Values

Measured Cost Reduction of	Change in Trade to GDP Ratio (p.p.) Internal	External	Migrant Stock	Per-Capita Income Variation	Aggregate Welfare
Main: $\kappa = 2.21$					
Internal Trade	38.7	-2.7	-1.8%	-3.6%	7.3%
External Trade	-3.1	17.8	0.8%	2.1%	2.5%
All Trade	34.1	13.7	-0.9%	-1.5%	9.6%
Migration	0.0	0.0	37.1%	-8.9%	0.4%
Internal Reform	38.6	-2.6	33.1%	-11.9%	7.7%
Everything	34.1	13.8	34.2%	-10.2%	10.1%
Medium: $\kappa = 5$					
Internal Trade	38.8	-2.7	-2.4%	-3.1%	7.3%
External Trade	-3.1	17.9	2.0%	0.9%	2.5%
All Trade	34.3	13.8	-0.5%	-2.0%	9.6%
Migration	0.0	0.2	64.6%	-9.0%	0.4%
Internal Reform	38.8	-2.5	57.5%	-11.5%	7.7%
Everything	34.3	13.9	58.6%	-10.6%	10.1%
High: $\kappa = 10$					
Internal Trade	39.1	-2.7	-1.4%	-2.6%	7.3%
External Trade	-3.1	17.9	4.0%	-0.9%	2.5%
All Trade	34.6	13.8	2.4%	-3.0%	9.6%
Migration	-0.1	0.4	104.5%	-7.9%	0.5%
Internal Reform	39.1	-2.3	94.7%	-10.0%	7.8%
Everything	34.7	14.0	95.2%	-10.0%	10.2%

Notes: Displays aggregate response to various counterfactuals as in the main text, for various values for κ. The top panel is the main set of results when $\kappa = 2.21$.

Table 13: Alternative Relative Changes in Bilateral Trade Costs, $\tau_{ni}^{2007}/\tau_{ni}^{2002}$

	Exporter								
Importer	North-east	Beijing Tianjin	North Coast	Central Coast	South Coast	Central Region	North-west	South-west	Abroad
Using Distance to Capture Symmetric Trade Costs									
Northeast		0.903	0.906	0.840	0.794	0.824	0.827	0.877	0.801
Beijing/Tianjin	0.838		0.903	0.906	0.888	0.795	0.733	0.857	0.790
North Coast	0.867	0.931		0.999	0.861	0.780	0.718	0.784	0.810
Central Coast	0.761	0.884	0.946		0.853	0.819	0.755	0.858	0.815
South Coast	0.773	0.932	0.876	0.917		0.804	0.721	0.808	0.938
Central Region	0.874	0.908	0.864	0.958	0.875		0.764	0.837	0.746
Northwest	0.951	0.907	0.862	0.958	0.851	0.828		0.877	0.682
Southwest	0.894	0.940	0.834	0.965	0.845	0.804	0.777		0.744
Abroad	0.869	0.924	0.919	0.977	1.046	0.764	0.644	0.793	
Using Strictly Symmetric Trade Costs (Unadjusted Head-Ries-Novy Measure)									
Northeast		0.870	0.886	0.800	0.784	0.848	0.887	0.886	0.834
Beijing/Tianjin	0.870		0.917	0.895	0.910	0.850	0.815	0.898	0.854
North Coast	0.886	0.917		0.972	0.868	0.821	0.787	0.809	0.863
Central Coast	0.800	0.895	0.972		0.884	0.886	0.850	0.910	0.892
South Coast	0.784	0.910	0.868	0.884		0.839	0.783	0.826	0.990
Central Region	0.848	0.850	0.821	0.886	0.839		0.795	0.821	0.755
Northwest	0.887	0.815	0.787	0.850	0.783	0.795		0.825	0.663
Southwest	0.886	0.898	0.809	0.910	0.826	0.821	0.825		0.768
Abroad	0.834	0.854	0.863	0.892	0.990	0.755	0.663	0.768	

Note: Displays relative changes in bilateral trade cost estimates using alternative trade cost measures. The top panel uses $log(distance_{ij})$ to capture symmetric trade costs instead of the directionless-pair fixed-effects from Section 4.2. The bottom panel uses strictly symmetric trade costs, or the unadjusted Head-Ries-Novy measure.

Table 14: Counterfactual Outcomes, Alternative Trade Cost Measures

Measured Cost Reduction of	Change in Trade to GDP Ratio (p.p.) Internal	External	Migrant Stock	Per-Capita Income Variation	Aggregate Welfare
Using Main Estimates					
Internal Trade	38.7	-2.7	-1.8%	-3.6%	7.3%
External Trade	-3.1	17.8	0.8%	2.1%	2.5%
All Trade	34.1	13.7	-0.9%	-1.5%	9.6%
Migration	0.0	0.0	37.1%	-8.9%	0.4%
Internal Reform	38.6	-2.6	33.1%	-11.9%	7.7%
Everything	34.1	13.8	34.2%	-10.2%	10.1%
Using Distance to Capture Symmetric Trade Costs					
Internal Trade	39.0	-2.7	-2.0%	-3.7%	7.3%
External Trade	-2.8	16.9	0.6%	1.7%	2.4%
All Trade	34.8	13.0	-1.3%	-1.7%	9.5%
Migration	0.0	0.0	37.1%	-8.9%	0.4%
Internal Reform	39.0	-2.6	33.0%	-12.1%	7.7%
Everything	34.7	13.0	33.8%	-10.5%	10.0%
Using Strictly Symmetric Trade Costs (Unadjusted Head-Ries-Novy Measure)					
Internal Trade	38.7	-2.4	-2.3%	-4.4%	7.3%
External Trade	-2.8	15.9	0.2%	1.6%	2.2%
All Trade	34.6	12.3	-2.1%	-2.6%	9.4%
Migration	0.0	0.0	37.1%	-8.9%	0.4%
Internal Reform	38.6	-2.4	32.3%	-12.6%	7.8%
Everything	34.6	12.3	32.6%	-11.2%	9.9%

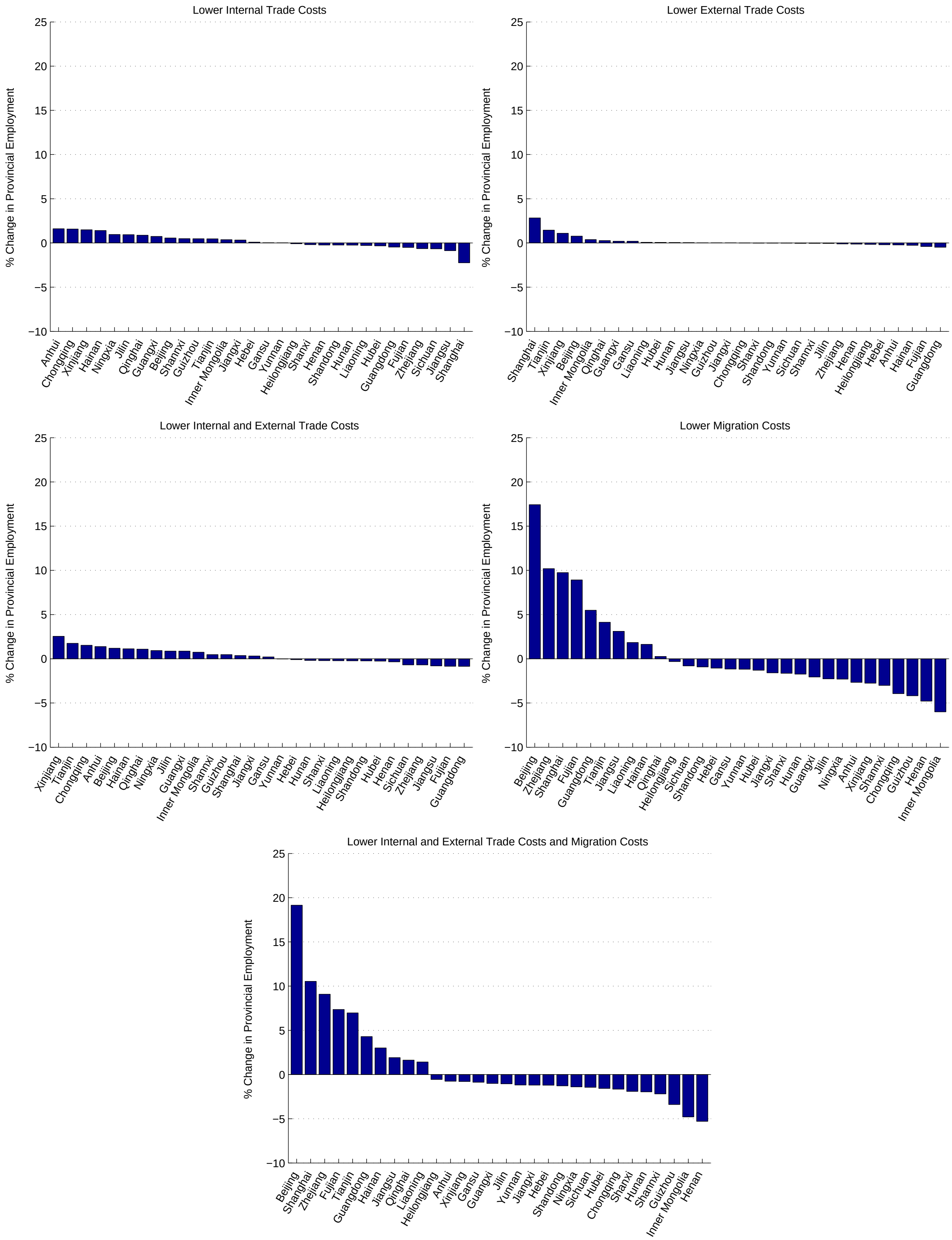
Notes: Displays aggregate response to various counterfactuals as in the main text, under various measures of trade costs. The top panel is the main results when $\hat{\tau}_{ni}$ is measured as in the main text.

Table 15: Counterfactual Outcomes, Worker Preference Differences

Measured Cost	Change in Trade to GDP Ratio (p.p.)		Migrant	Per-Capita Income	Aggregate Outcomes	
Reduction of	Internal	External	Stock	Variation	Real GDP	Welfare
Main Estimates						
Internal Trade	38.7	-2.7	-1.8%	-3.6%	7.9%	7.3%
External Trade	-3.1	17.8	0.8%	2.1%	3.0%	2.5%
All Trade	34.1	13.7	-0.9%	-1.5%	10.8%	9.6%
Migration	0.0	0.0	37.1%	-8.9%	0.9%	0.4%
Internal Reform	38.6	-2.6	33.1%	-11.9%	8.8%	7.7%
Everything	34.1	13.8	34.2%	-10.2%	11.7%	10.1%
When z's are Utility Differences, not Productivity Differences						
Internal Trade	38.7	-2.7	-1.7%	-3.6%	7.9%	7.3%
External Trade	-3.1	17.8	0.8%	1.9%	3.0%	2.5%
All Trade	34.1	13.7	-0.9%	-1.6%	10.8%	9.6%
Migration	-0.1	0.2	35.7%	-9.7%	-0.6%	1.0%
Internal Reform	38.6	-2.5	31.9%	-12.8%	7.3%	8.3%
Everything	34.0	13.9	32.9%	-11.1%	10.2%	10.7%
When z's and μ_{ni} are Uutility, no Productivity Differences or Migration Costs						
Internal Trade	38.8	-2.7	-1.6%	-4.0%	7.8%	7.4%
External Trade	-3.1	17.9	0.7%	2.7%	3.1%	2.4%
All Trade	34.2	13.8	-0.8%	-1.3%	10.8%	9.7%
Migration	0.0	0.0	34.3%	-5.9%	1.9%	0.3%
Internal Reform	38.6	-2.6	30.6%	-9.7%	9.6%	7.7%
Everything	34.1	13.8	31.7%	-7.3%	12.7%	10.0%

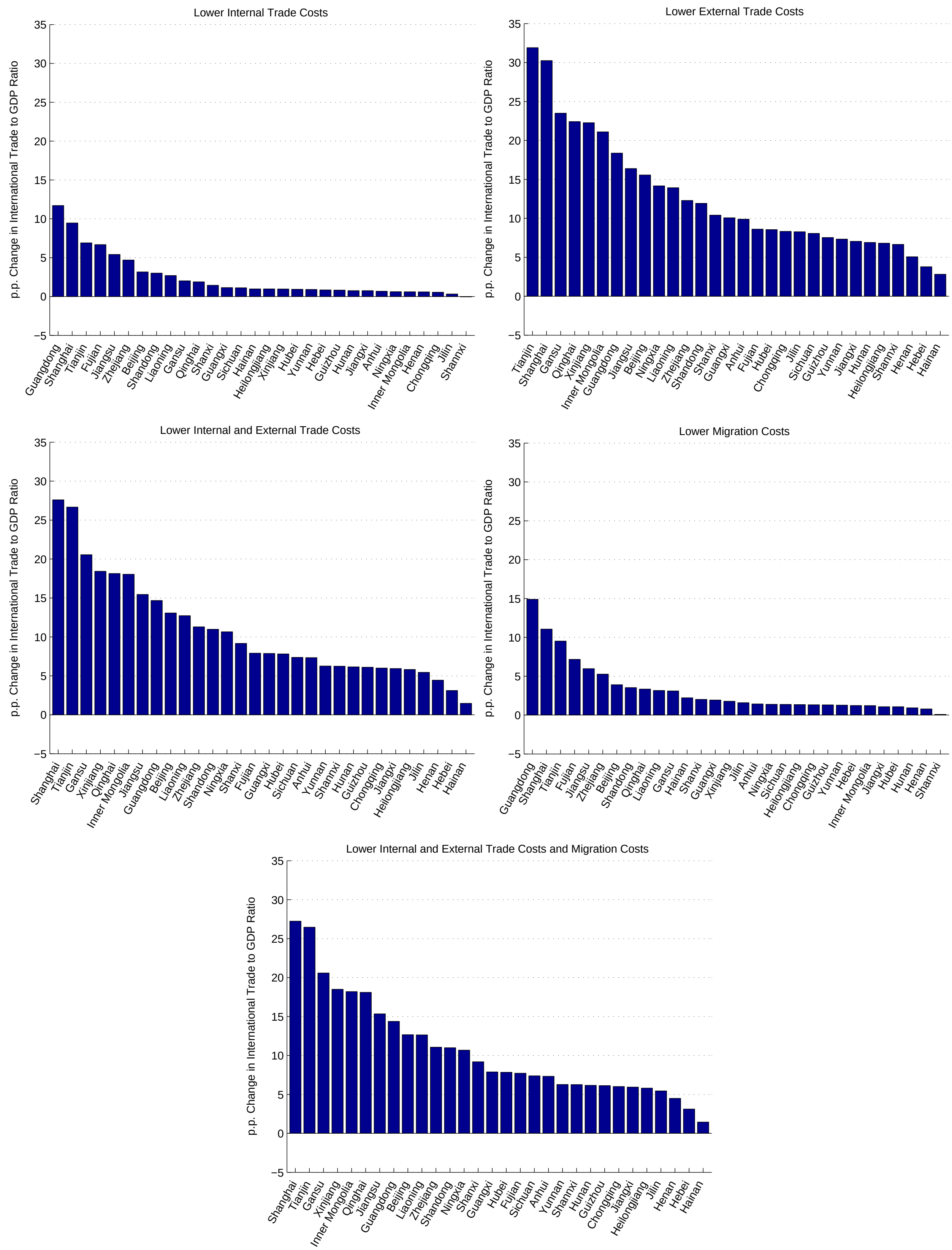
Notes: Displays aggregate response to various counterfactuals as in the main text, under the alternative assumption that worker heterogeneity in z represents utility differences from migration. That is, μ_{ni} is the only real resource migration cost. In the last panel, even the μ_{ni} costs are welfare costs.

Figure 10: Change in Provincial Employment



Note: Displays the percentage change in total employment across provinces for various counterfactual experiments.

Figure 11: Change in International Trade/GDP



Note: Displays the percentage point change in the ratio of international trade flows (imports plus exports) to GDP across provinces for various counterfactual experiments.

Appendix A: Proofs of Propositions

Proposition 1: *Given real incomes for each region V_i, migration costs between all regional pairs μ_{ij}, and heterogeneous productivity distributed $F_z(x)$, the share of region i workers that migrate to region j is*

$$m_{ij} = \frac{\left(V_j \mu_{ij}\right)^{\kappa}}{\sum_{k=1}^{N}\left(V_k \mu_{ik}\right)^{\kappa}}.$$

Proof: The share of people from region i that migrate to region j is the probability that each individual's potential payoff from region j exceeds that from any other region. Specifically,

$$m_{ij} \equiv Pr\left(\mu_{ij} z_j V_j \geq \max_{k \neq j}\left\{\mu_{ik} z_k V_k\right\}\right).$$

Since $Pr(z_j \leq x) \equiv e^{-x^{-\kappa}}$ by assumption of Frechet distributed worker productivity, we have $Pr(\mu_{ij} z_j V_j \leq x) = Pr(z_j \leq x/\mu_{ij} V_j) = e^{-(x/\mu_{ij} V_j)^{-\kappa}}$. The distribution of net income across workers from i in region j is therefore also Frechet. Similarly, the distribution of the highest net real income in all other regions is described by

$$\begin{aligned} Pr\left(\max_{k \neq j}\left\{\mu_{ik} z_k V_k\right\} \leq x\right) &= \prod_{k \neq j} Pr\left(\mu_{ik} z_k V_k \leq x\right), \\ &= \prod_{k \neq j} Pr\left(z_k \leq x/\mu_{ik} V_k\right), \\ &= \prod_{k \neq j} e^{-(x/\mu_{ik} V_k)^{-\kappa}}, \\ &= e^{-\left(x/\left(\sum_{k \neq j}(\mu_{ik} V_k)^{\kappa}\right)^{1/\kappa}\right)^{-\kappa}}, \end{aligned}$$

which is also Frechet.

Returning to the original m_{ij} expression, let $X = \mu_{ij} z_j V_j$ and $Y = \max_{k \neq j}\left\{\mu_{ik} z_k V_k\right\}$, which are Frechet distributed with parameters $s_X = \mu_{ij} V_j$ and $s_Y = \left(\sum_{k \neq j}\left(\mu_{ik} V_k\right)^{\kappa}\right)^{1/\kappa}$. By the Law of Total Probability,

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

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

$$\begin{aligned} m_{ij} &= 1 + \int_{u=\infty}^{u=0} e^{-(s_X^\kappa + s_Y^\kappa)u} s_X^\kappa du, \\ &= 1 - s_Y^\kappa \int_0^\infty e^{-(s_X^\kappa + s_Y^\kappa)u} du, \\ &= 1 - \frac{s_Y^\kappa}{s_X^\kappa + s_Y^\kappa} = \frac{\left(\mu_{ij} V_j\right)^\kappa}{\sum_{k=1}^N \left(V_k \mu_{ik}\right)^\kappa}, \end{aligned}$$

which is the result. ■

Proposition* 2*: *If worker productivity z_i is distributed Frechet with variance parameter κ, and agents are able to migrate between regions at cost μ_{ij}, then the expected real income net of migration costs for workers from region i is*

$$V_i^0 = \tilde{\gamma} V_i m_{ii}^{-1/\kappa},$$

and aggregate average real income (welfare) is therefore

$$W = \tilde{\gamma} \sum_{i=1}^N \lambda_i^0 V_i m_{ii}^{-1/\kappa},$$

where $\tilde{\gamma} = \Gamma\left(1 - \kappa^{-1}\right)$ and $\lambda_i^0 = \frac{L_i^0}{\sum_{j=1}^N L_j^0}$ is the share registered in region i.

Proof: A worker from region i has heterogeneous productivity across all potential regions in China. These productivity are i.i.d. $Frechet(\kappa, 1)$ across all workers and regions. Each worker will reside in the location that maximizes real income net of migration costs $\mu_{ij} z_j V_j$. The probability that a given person's welfare is below x is the probability that *no* region gives utility above x. The probability that region $j's$ payoff for a person from region i is below x is $e^{-\left(x/\mu_{ij}V_j\right)^{-\kappa}}$. The probability that they are all below x is the product of this across all potential regions,

$$F_{U_i}(x) = \prod_{j=1}^N e^{-\left(x/\mu_{ij}V_j\right)^{-\kappa}} = e^{-\left(x/\left[\sum_{j=1}^N \left(\mu_{ij}V_j\right)^\kappa\right]^{1/\kappa}\right)^{-\kappa}}.$$

To get our result, note that if $X \sim Frechet(\kappa, s)$ then $Pr(X < x) \equiv F(x) = e^{-(x/s)^{-\kappa}}$ and $E[X] = s\Gamma\left(1 - \kappa^{-1}\right) \equiv s\tilde{\gamma}$, where $\Gamma(\cdot)$ is the Gamma function. So, the utility of workers from region i after migration decisions – distributed according to $F_{U_i}(x)$ above – is Frechet with $E[U_i] = \tilde{\gamma}\left[\sum_{j=1}^N \left(\mu_{ij} V_j\right)^\kappa\right]^{1/\kappa}$. As real income and welfare are synonymous, $V_i^0 \equiv E[U_i]$. From proposition 1, $m_{ii} = \frac{V_i^\kappa}{\sum_{j=1}^N (\mu_{ik} V_k)^\kappa}$ and therefore $V_i^0 = \tilde{\gamma} V_i m_{ii}^{-1/\kappa}$. Aggregate welfare is the mean across all regions of registration, weighted by registration population shares $\lambda_i^0 = L_i^0 / \sum_{j=1}^N L_j^0$, $W = \tilde{\gamma} \sum_{i=1}^N \lambda_i^0 V_i m_{ii}^{-1/\kappa}$. ■

Proposition 3: *The total supply of effective labour in region n is*

$$H_n = \sum_{i=1}^{N} \tilde{\gamma} \mu_{in} m_{in}^{\frac{\kappa-1}{\kappa}} L_i^0.$$

Moreover, $h_{in} = \tilde{\gamma}\mu_{in} m_{in}^{-1/\kappa}$ is the average units of effective labour for workers from region n that work in region i, and therefore $H_n = \sum_{i=1}^{N} h_{in} m_{in} L_i^0$.

Proof: Worker productivity follows a Frechet distribution with mean $\tilde{\gamma}$. The productivity of workers from region i that work in region j will follow a different distribution. By the multiplication rule of probabilities,

$$Pr\left(z_j \leq x \mid \mu_{ij} V_j z_j \geq \max_{k \neq j} \{\mu_{ik} V_k z_k\}\right) = \frac{Pr\left[\left(z_j \leq x\right) \cap \left(\mu_{ij} V_j z_j \geq \max_{k \neq j} \{\mu_{ik} V_k z_k\}\right)\right]}{Pr\left(\mu_{ij} V_j z_j \geq \max_{k \neq j} \{\mu_{ik} V_k z_k\}\right)}. \tag{20}$$

From Proposition 1, the probability of a worker from i to work in region j (the denominator of the above) is m_{ij}. The numerator is

$$Pr\left[\left(z_j \leq x\right) \cap \left(\mu_{ij} V_j z_j \geq \max_{k \neq j} \{\mu_{ik} V_k z_k\}\right)\right] \quad = \quad Pr\left[\max_{k \neq j} \{\mu_{ik} V_k z_k\} \leq \mu_{ij} V_j z_j \leq \mu_{ij} V_j x\right].$$

We saw in Proposition 1 that $X = \mu_{ij} V_j z_j$ and $Y = \max_{k \neq j} \{\mu_{ik} V_k z_k\}$ are both Frechet distributed random variables. Denote their CDFs $F(x)$ and $G(y)$, with means $\tilde{\gamma}\mu_{ij} V_j$ and $\tilde{\gamma}\left(\sum_{k \neq i} \left(\mu_{ik} V_k\right)^{\kappa}\right)^{1/\kappa}$, respectively. To ease notation, define $B = \left(\sum_{k \neq i} \left(\mu_{ik} V_k\right)^{\kappa}\right)^{1/\kappa}$. Given a particular value for Y,

$$\begin{aligned} Pr\left[y \leq \mu_{ij} V_j z_j \leq \mu_{ij} V_j x\right] &= Pr\left[\mu_{ij} V_j z_j \leq \mu_{ij} V_j x\right] - Pr\left[\mu_{ij} V_j z_j \leq y\right], \\ &= F\left(\mu_{ij} V_j x\right) - F\left(y\right). \end{aligned}$$

Hence, by the Law of Total Probability,

$$\begin{aligned} Pr\left[\max_{k \neq j} \{\mu_{ik} V_k z_k\} \leq \mu_{ij} V_j z_j \leq \mu_{ij} V_j x\right] &= \int_0^{\mu_{ij} V_j z_j} \left[F\left(\mu_{ij} V_j x\right) - F\left(y\right)\right] dG\left(y\right), \\ &= G\left(\mu_{ij} V_j x\right) F\left(\mu_{ij} V_j x\right) - \int_0^{\mu_{ij} V_j x} F(y) dG(y). \end{aligned}$$

Solve for the first term,

$$\begin{aligned} G\left(\mu_{ij} V_j x\right) F\left(\mu_{ij} V_j x\right) &= e^{-\left(\frac{\mu_{ij} V_j x}{\gamma B}\right)^{-\kappa}} e^{-\left(\frac{x}{\gamma}\right)^{-\kappa}}, \\ &= e^{-\left(\frac{x}{\gamma}\right)^{-\kappa}\left[\frac{B^{\kappa}}{\left(\mu_{ij} V_j\right)^{\kappa}} + 1\right]}, \\ &= e^{-\left(\frac{x}{\gamma}\right)^{-\kappa}\left[\frac{\sum_{k=1}^{N} \left(\mu_{ik} V_k\right)^{\kappa}}{\left(\mu_{ij} V_j\right)^{\kappa}}\right]}, \\ &= e^{-(x/\gamma)^{-\kappa}/m_{ij}}, \end{aligned}$$

where the last line follows from equation 3.

Next, to solve the second term, find the PDF of Y ($dG(y)$). Since $G(y)$ is Frechet with mean $\tilde{\gamma}B$,

$$dG(y) = \frac{\kappa}{B}\left(\frac{y}{B}\right)^{-\kappa-1} e^{-(y/B)^{-\kappa}}.$$

With this, and defining $A \equiv \sum_{k=1}^{N} (\mu_{ik}V_k)^{\kappa}$, we have

$$\begin{aligned}
\int_0^{\mu_{ij}V_j x} F(y)dG(y) &= \int_0^{\mu_{ij}V_j x} e^{-\left(\frac{y}{\mu_{ij}V_j}\right)^{-\kappa}} e^{-\left(\frac{y}{B}\right)^{-\kappa}} \frac{\kappa}{B}\left(\frac{y}{B}\right)^{-\kappa-1} dy, \\
&= \int_0^{\mu_{ij}V_j x} e^{-\left(\frac{y}{A}\right)^{-\kappa}} \frac{\kappa}{B}\left(\frac{y}{B}\right)^{-\kappa-1} dy, \\
&= \left(\frac{B}{A}\right)^{\kappa} \int_0^{\mu_{ij}V_j x} e^{-\left(\frac{y}{A}\right)^{-\kappa}} \frac{\kappa}{A}\left(\frac{y}{A}\right)^{-\kappa-1} dy, \\
&= \left(\frac{B}{A}\right)^{\kappa} e^{-\left(\frac{\mu_{ij}V_j x}{A}\right)^{-\kappa}}.
\end{aligned}$$

So, using these two results,

$$\begin{aligned}
Pr\left[\max_{k\neq j}\{\mu_{ik}V_k z_k\} \leq \mu_{ij}V_j z_j \leq \mu_{ij}V_j x\right] &= \left[1 - \left(\frac{B}{A}\right)^{\kappa}\right] e^{-\left(\frac{\mu_{ij}V_j x}{A}\right)^{-\kappa}}, \\
&= \frac{\left(\mu_{ij}V_j\right)^{\kappa}}{A^{\kappa}} e^{-\left(\frac{\mu_{ij}V_j x}{A}\right)^{-\kappa}}, \\
&= m_{ij} e^{-\left(x/\left(A/\mu_{ij}V_j\right)\right)^{-\kappa}}.
\end{aligned}$$

The m_{ij} therefore cancels out (recalled equation 20), and the conditional distribution of z_j is

$$Pr\left(z_j \leq x \mid \mu_{ij}V_j z_j \geq \max_{k\neq j}\{\mu_{ik}V_k z_k\}\right) = e^{-\left(x/\left(A/\mu_{ij}V_j\right)\right)^{-\kappa}},$$

which is Frechet with mean $\tilde{\gamma}A/\mu_{ij}V_j = \tilde{\gamma}m_{ij}^{-1/\kappa}$.

Finally, since all migrants incur a migration cost modeled as a real resource cost (a time loss, or a direct productivity reduction), the average units of effective labour of migrants net of the migration cost is $h_{in} = \tilde{\gamma}\mu_{in}m_{in}^{-1/\kappa}$ and our result follows. ■

Appendix B: Modeling Migrant Remittances

We explore how migrant remittances affect our key results. All of the production components of the model are unaffected by the presence of migrant remittances. The labour migration conditions, however, are. In addition, remittance payments will create trade imbalances. We consider a special type of remittances that yield tractable expressions: migrant remittances and receipts by non-migrants are both proportional to their nominal income (though at potentially different rates).

Specifically, let ρ be the fraction of migrant earnings remitted back to non-migrants in their home provinces, so a migrant from n working in i with productivity z_i receives income $v_i z_i \mu_{ni}(1-\rho)$. This rate is common across all migrants, regardless of where they work. Non-migrants in the home province receive total remittances in proportion to their nominal income. Consequently, $\varsigma_n \geq 1$ is the (gross) subsidy rate that augments their income, so a non-migrant's income in region n is $v_n z_n \varsigma_n$.

As the average human capital of migrants from n working in i is $\tilde{\gamma}\mu_{ni} m_{ni}^{-1/\kappa}$, total nominal income of the $m_{ni} L_n^0$ migrants is then $\tilde{\gamma}\mu_{ni} m_{ni}^{(\kappa-1)/\kappa} v_i L_n^0$. With this, and the remittance rate ρ, the total received by non-migrants in region n from migrants to all destinations $i \neq n$ is $\sum_{i\neq n} \rho \tilde{\gamma}\mu_{ni} m_{ni}^{(\kappa-1)/\kappa} v_i L_n^0$. The subsidy rate is then

$$\varsigma_n = 1 + \frac{\sum_{i\neq n} \rho \tilde{\gamma}\mu_{ni} m_{ni}^{(\kappa-1)/\kappa} v_i}{\tilde{\gamma} m_{nn}^{(\kappa-1)/\kappa} v_n}.$$

It is now possible, and convenient, to define $\tilde{\mu}_{ni}$ as the effective migration cost that combines the real migration cost μ_{ni} adjusted for remittances

$$\tilde{\mu}_{ni} \equiv \mu_{ni} R_{ni} / \varsigma_n, \tag{21}$$

where $R_{ni} = (1-\rho)$ if $n \neq i$ and $R_{ni} = \varsigma_n$ if $n = i$. Combining the above yields

$$\varsigma_n = \left[1 - \sum_{i\neq n} \tilde{\mu}_{ni} \frac{\rho}{1-\rho} \left(\frac{m_{ni}}{m_{nn}}\right)^{\frac{\kappa-1}{\kappa}} \left(\frac{v_i}{v_n}\right)\right]^{-1} \tag{22}$$

The share of migrants m_{ni} is then identical to before but with $\tilde{\mu}_{ni}$ taking the place of μ_{ni} in the final expression. Specifically,

$$\begin{aligned} m_{ni} &= Pr\left(V_i z_i R_i \mu_{ni} \geq \max_{j\neq i}\left\{R_j V_j z_j \mu_{nj}\right\}\right), \\ &= Pr\left(V_i z_i \tilde{\mu}_{ni} \geq \max_{j\neq i}\left\{V_j z_j \tilde{\mu}_{nj}\right\}\right) = \frac{(V_i \tilde{\mu}_{ni})^\kappa}{\sum_{j=1}^N \left(V_j \tilde{\mu}_{nj}\right)^\kappa}. \end{aligned} \tag{23}$$

The estimates for μ_{ni} in the baseline model without remittances is now simply interpreted as remittance-adjusted migration costs $\tilde{\mu}_{ni}$. Recall that our initial equilibrium real incomes V_n, given observed migration shares m_{ni}, did not depend on migration costs. As before, $\tilde{\mu}_{ni} = (m_{ni}/m_{nn})^{1/\kappa} V_n / V_i$.

Given data on m_{ni}, we can solve for equilibrium values for nominal income v_n, effective labour H_n, expenditures $v_n H_n$, and real migration costs μ_{ni} as follows. First, note that there is a trade imbalance for each region n created by flows in from migrants working outside province n and flows out from migrants working in province n but who are not registered there. Total expenditures X_n

and total factor payments $v_n H_n$ are therefore related by

$$X_n = v_n H_n - \left[\sum_{i \neq n} \rho v_n \tilde{\gamma} \mu_{in} m_{in}^{\frac{\kappa-1}{\kappa}} L_i^0 - \sum_{i \neq n} \rho v_i \tilde{\gamma} \mu_{ni} m_{ni}^{\frac{\kappa-1}{\kappa}} L_n^0 \right], \tag{24}$$

The first term in the brackets are outflows from region n by migrants working there. The second term are inflows from workers registered in region n but working elsewhere. Perfect competition ensures total factor payments equal total firm revenue, which are solved through trade flows π_{ni} using

$$v_n H_n = \frac{\beta + \eta}{\alpha} \sum_{i=1}^{N+1} X_i \pi_{in}. \tag{25}$$

Combine equations 24 and 25 to yield

$$v_n H_n = \frac{\beta + \eta}{\alpha} \sum_{k=1}^{N+1} \left(v_k H_k - \rho \left[\sum_{i \neq k} v_k \tilde{\gamma} \mu_{ik} m_{ik}^{\frac{\kappa-1}{\kappa}} L_i^0 - \sum_{i \neq k} v_i \tilde{\gamma} \mu_{ki} m_{ki}^{\frac{\kappa-1}{\kappa}} L_k^0 \right] \right) \pi_{kn}, \tag{26}$$

which will be useful later to solve for nominal incomes v_n.

Finally, as before, effective workers in region n are still (as before) $H_n = \sum_{i=1}^{N} \tilde{\gamma} \mu_{in} m_{in}^{\frac{\kappa-1}{\kappa}} L_i^0$, which implies

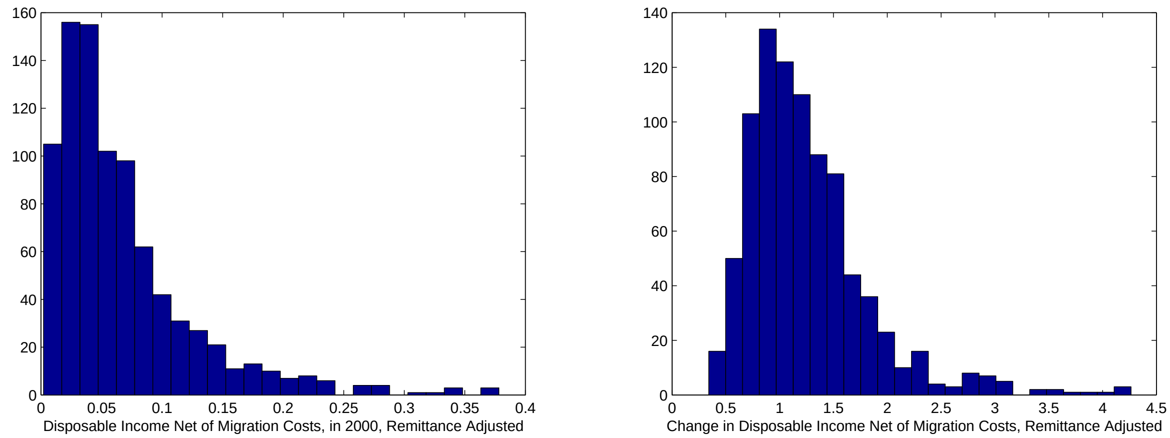
$$\begin{aligned} V_n H_n &= \sum_{i=1}^{N} V_n \tilde{\gamma} \mu_{in} m_{in}^{\frac{\kappa-1}{\kappa}} L_i^0, \\ &= V_n \tilde{\gamma} m_{nn}^{\frac{\kappa-1}{\kappa}} L_n^0 + \sum_{i \neq n} V_n \tilde{\gamma} \tilde{\mu}_{in} \frac{\varsigma_i}{1-\rho} m_{in}^{\frac{\kappa-1}{\kappa}} L_i^0, \\ &= V_n \tilde{\gamma} m_{nn}^{\frac{\kappa-1}{\kappa}} L_n^0 + \sum_{i \neq n} \tilde{\gamma} m_{ii}^{-1/\kappa} V_i \frac{\varsigma_i}{1-\rho} m_{in} L_i^0, \end{aligned} \tag{27}$$

So, equations 21 through 27 define a system of equations sufficient to solve for the unknowns $(H_n, V_n, v_n, \tilde{\mu}_{ni}, \mu_{ni}, \varsigma_n)$ for any remittance level ρ given data on migration m_{ni}, trade π_{ni}, and registrations L_n^0. The algorithm to solve this system is simple:

1. Guess subsidy rate ς_n, solve V_n from equation 27 using real GDP per capita data for $V_n H_n$;
2. With this, solve for H_n using the same real GDP data;
3. Also with V_n, and data on m_{ni}, solve for $\tilde{\mu}_{ni}$ from equation 23;
4. With $\tilde{\mu}_{ni}$, solve for real migration costs μ_{ni} from equation 21;
5. With H_n and μ_{ni}, solve for nominal income v_n from equation **??**;
6. Finally, with v_n and μ_{ni}, solve for a new subsidy rate ς_n' from equation 22;
7. Use ς_n' as new guess and repeat until ς_n and ς_n' converge.

Figure 12: Histogram of Bilateral Migration Costs

(a) Migration Cost Parameter μ_{ij} in 2000 (b) Relative Changes in μ_{ij}



Notes: Displays the measure of migration costs captured by the fraction of income remaining after migration costs are paid. We denote this value as μ_{ij} in the text. Panel (b) displays the ratio of μ_{ij} in 2005 to its year 2000 level. Values for relative changes above one represent *reductions* in migration costs.

With the model solved, the quantitative analysis can proceed in a similar fashion to the no-remittance case. Before repeating our main counterfactuals, consider the magnitude of our real migration costs μ_{ni} with remittances to our baseline estimates. The principle driver of differences between the two is the term $(1-\rho)/\varsigma_n$ that were treated as a real migration cost in our baseline model but are now treated as a monetary transfer from migrants to non-migrants rather than a real resource cost.

We display our new estimates of μ_{ni} in Figure 12 using the high remittance level of $\rho = 0.5$. The magnitudes are similar to the baseline case, though overall real migration costs are lower. In terms of changes, the average change in migration costs are $\hat{\mu}_{ij} = 1.25$ – very similar to the $\hat{\mu}_{ni} = 1.24$ from our baseline model.

We repeat all of our main experiments for various remittance rates and find very little is sensitive. Welfare gains fall slightly across all experiments, as does the affect of each counterfactual on income inequality across regions. Migration flows are also similar, with the exception of internal trade liberalization. Before, workers found it beneficial to return home if internal trade costs declined. If remittances are sufficiently high, the number of migrants increases.

Table 16: Counterfactual Aggregate Outcomes

Measured Cost Reduction of	p.p. Change in Trade/GDP Ratio: Internal	p.p. Change in Trade/GDP Ratio: External	Migrant Stock	Per-Capita Income Variation	Aggregate Welfare
No Remittances ($\rho = 0.00$)					
Internal Trade	38.7	-2.7	-1.8%	-3.6%	7.3%
External Trade	-3.1	17.8	0.8%	2.1%	2.5%
All Trade	34.1	13.7	-0.9%	-1.5%	9.6%
Migration	0.0	0.0	37.1%	-8.9%	0.4%
Internal Reform	38.6	-2.6	33.1%	-11.9%	7.7%
Everything	34.1	13.8	34.2%	-10.2%	10.1%
Low Remittances ($\rho = 0.10$)					
Internal Trade	38.7	-2.7	-1.4%	-3.4%	7.3%
External Trade	-3.1	17.9	0.9%	2.1%	2.4%
All Trade	34.2	13.8	-0.4%	-1.3%	9.6%
Migration	0.0	0.0	36.8%	-8.8%	0.4%
Internal Reform	38.6	-2.6	33.4%	-11.7%	7.7%
Everything	34.1	13.8	34.6%	-9.9%	10.0%
Moderate Remittances ($\rho = 0.25$)					
Internal Trade	38.7	-2.6	-0.6%	-3.2%	7.2%
External Trade	-3.1	18.0	1.1%	2.3%	2.4%
All Trade	34.3	14.0	0.4%	-0.9%	9.5%
Migration	0.0	-0.1	36.3%	-8.5%	0.3%
Internal Reform	38.6	-2.6	34.0%	-11.2%	7.6%
Everything	34.2	13.9	35.3%	-9.3%	9.9%
High Remittances ($\rho = 0.50$)					
Internal Trade	38.9	-2.6	1.0%	-2.6%	7.2%
External Trade	-3.0	18.4	1.4%	2.6%	2.2%
All Trade	34.6	14.3	2.2%	-0.1%	9.3%
Migration	0.2	-0.2	35.5%	-7.2%	0.2%
Internal Reform	38.7	-2.7	35.2%	-9.5%	7.3%
Everything	34.5	14.0	36.8%	-7.3%	9.4%

Notes: Displays aggregate response to various counterfactuals. Trade costs and migration costs are reduced by the amount we measure in the text. The change in trade's share of GDP is displayed in terms of percentage point changes. 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.