Internal Migration, Remittances and Economic Development[*]

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October, 2022

Abstract

We develop a quantitative spatial equilibrium model with endogenous migration and remittance decisions within households to examine the joint effect of migration and remittances on economic development. We apply the model to internal migration in China. Counterfactual analysis of the calibrated model shows that the presence of remittances increases migration and welfare, reduces regional inequality and facilitates structural change. Compared to a conventional single-person migration model, our household model suggests a larger reduction in regional inequality and stronger reallocation of employment from agricultural to manufacturing and services in response to the decline in migration costs over the period of 2000 to 2010.

Keywords. remittances, migration, structural change, spatial equilibrium

JEL Classification. O1, R1, R2

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[*] We thank Jin Li, Rachel Ngai, Steve Redding, Zhigang Tao, Xiaodong Zhu and participants at the HKU Macro Brownbag Seminar and the 2021 China Meeting of the Econometric Society for helpful comments. An earlier version of this paper circulated under the title "Internal Migration, Remittances and Structural Change". Financial support from HKGRF (project codes: 17502920) is greatly appreciated.

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1 Introduction

Migrants' remittances represent an important source of external financing in many developing countries. In 2018, the inflow of remittances to developing countries reached a record high of US \$529 billion (World Bank, 2019). This amount is about 7.63% of these countries' gross domestic product (GDP) and is close to their foreign direct investment (FDI) flows in 2018. Although existing research has shown that remittances help to improve human capital investment (Bansak and Chezum, 2009), reduce inequality (Stark et al., 1986), and promote economic growth (Giuliano and Ruiz-Arranz, 2009), little is known about the interaction between migration and remittances. In this paper, we build a quantitative framework with endogenous household (domestic) migration and remittance decisions and shed light on their joint effects on regional development in China.

To motivate our model, we first describe migrants' remittance behavior using survey data from the China Migrants Dynamic Survey. According to the survey, it is common for migrants to send remittances to their family members at home: about 73% of surveyed migrants sent remittances in 2010. Additional regression analysis reveals that the amount of remittance increases with the migrants' earnings, decreases with their expenditure, decreases with the number of family members that migrate together and increases with the left-behind members' need for income. These facts motivate us to model remittances as altruistic, endogenous transfers to household members to increase their consumption.

We introduce endogenous household decisions of migration and remittances in a quantitative spatial general equilibrium model with multiple sectors (Fajgelbaum and Redding, 2018; Hao et al., 2020) and apply the model to China's internal migration. In particular, we assume that each household consists of three members, two working-age adults (workers) and one that is either too young or too old to work. One or both of the workers can choose to migrate out of their hometown and work in a different location. The household incurs an additional separation cost if only one of the workers migrates. Migrants can remit some of their income to members that have not migrated. Conditional on migration decisions, optimal transfers are determined by maximizing an integral utility of all household members. Different locations feature different prices, and amenity levels and wages differ by location and sector. Households have idiosyncratic preferences over the two workers' choices of locations and sectors due to extreme-value type of preference shocks. Given these assumptions, we derive closed-form formulas of optimal remittances and migration flows. Reductions in migration costs and higher productivities in one location can benefit households in other regions through trade, migration and remittance linkages.

A key feature of economic development is structural change, i.e., employment being reallocated from agriculture to manufacturing and services. To capture the effect of migration and remittances on this, we assume that there are three sectors in our model: agriculture, manufacturing and non-traded services. Following the macro literature on structural change (Herrendorf et al., 2014), we allow consumer preferences to be non-homothetic. In our model, remittances can affect structural change through multiple mechanisms. First, in a model with constant consumption shares across sectors (Cobb-Douglas preferences), remittances will increase the local production share of non-tradables because, unlike tradables, the increase in demand due to remittances for non-tradables falls exclusively onto remittance-receiving regions.[1] Second, the disproportional increase in the demand for local non-tradables will increase the relative price of non-tradables to tradables. When consumers see tradables and non-tradables as complements, a typical assumption in models where structural change is driven by supply-side forces (Ngai and Pissarides, 2007), the change in relative prices further induces consumers to allocate more income to the consumption of non-tradables because tradables and non-tradables are complements. Finally, our non-homothetic preferences (Stone-Geary) generate a direct income effect: as consumers become wealthier due to remittances, they consume more services and fewer agricultural goods. All mechanisms suggest a faster structural change, especially in remittance-receiving regions, but the magnitude of the effect and the relative strength of each mechanism remains a quantitative question.

We calibrate our model to the equilibrium of the Chinese economy (284 cities) in 2010. First, we estimate some model parameters without solving the full general equilibrium model. Following the gravity literature in international trade, we parameterize trade costs by assuming they are functions of geographical characteristics and distances. Then, based on the estimated trade costs, we use the goods market clearing conditions to back out sectoral productivities in different prefectures. With these parameters, we obtain the model-implied sectoral prices, which we combine with each region's sectoral consumption shares in the data to estimate the Stone-Geary preferences (Herrendorf et al., 2013). In the second step, we jointly estimate the remaining model parameters by solving the full model and matching data moments. In particular, we parameterize migration costs as in Fan (2019) and find parameter values to minimize the difference between migration shares in the model and those in the data. We use city-sector-specific amenity levels to match the observed sectoral employment in each city. We estimate the utility weights of household members and the "separation cost" when the two working-age adults work in different locations to match the share of remittances in migrants' income and the share of joint migration among migrant households.

Equipped with the calibrated model, we consider two sets of counterfactual experiments. In the first counterfactual, we evaluate the direct effect of remittances by prohibiting migrants from sending transfers to the household members at home, capturing a scenario with extremely

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[1] This mechanism is similar to the "Dutch disease" phenomenon in Corden and Neary (1982), who prove that, in their model, a capital inflow in a small open economy leads to de-industrialization.

high costs of sending remittances. Banning remittances reduces benefits from migrating from a low-wage city-sector to a high-wage one. Our model predicts that it would reduce aggregate migration in China by 2.9%. It would also reduce the real income in the receiver cities by 5.0% and increase the real income in the remitter cities by 3.9%. Income inequality across Chinese cities also rises – the variance of log real income increases from 0.10 to 0.18, equivalent to a 77.8% increase.

Regarding structural change, banning remittances raises the nationwide agricultural employment share by 0.9 percentage points (p.p), and reduces the employment share of manufacturing and services by 0.4 p.p and 0.5 p.p, respectively. The effect of banning remittances is also heterogeneous across regions. Receiver cities see an even stronger decline in agricultural employment and a larger increase in service employment than the nationwide changes, while top remitter cities experience the opposite. We decompose the impact of remittances on structural change into the three mechanisms mentioned above as well as the effect of reduced migration by turning on one mechanism at a time using alternative models with different preferences (Cobb-Douglas or constant elasticity of substitution) and a "constrained" equilibrium in which we fix the migration flows to the initial equilibrium. We find that the unequal demand effect generally explains about half of the predicted changes of sectoral shares in response to banning remittances, while the income and migration effects each explain about one-fourth. The price effect is negligible in this counterfactual.

The second counterfactual studies the impact of migration cost reduction and productivity changes over the period of 2000-2010. We estimate the migration cost and productivity changes by matching the change in migration flows and real GDP per worker in each city-sector during this decade while keeping other model parameters fixed at the 2010 baseline equilibrium. We find that the majority of the rise in migration and structural transformation within this period is explained by the reduction in migration cost. The rise in migration also increases the share of remittances in total GDP from 1.1% to 2.1% and contributes to large reductions in regional inequality in income and household welfare. On the other hand, consistent with dramatic GDP growth in almost all city-sectors, we estimate large productivity growth, which has a much larger impact on nationwide real income and household welfare levels, and to a smaller extent, regional inequality. However, since receiver cities experience faster productivity growth on average, productivity changes alone lead to a small decline in the share of remittances in total GDP.

To highlight the effect of remittances in the second counterfactual, we estimate a typical single-person migration model as in earlier studies (Fan, 2019; Hao et al., 2020). Though qualitatively similar, our household model predicts stronger structural transformation and a larger reduction in income and welfare inequality in response to the reduction in migration cost. One potential explanation is that the household model allows transfers of income between family members, and the share of remittances in GDP increases when migration costs decline, amplifying the effects of remittances on structural change and inequality reduction. In contrast, because the share of remittances declines as we change productivities from the 2000 to 2010 levels, the predicted changes in sectoral employment shares and income and welfare inequality are smaller in the household model than those in the single-person model. Therefore, it is important to incorporate household migration and remittance decisions to better understand the impact of productivities and migration frictions on economic development.

Our work contributes to three strands of literature. First, it contributes to a vast and rapidly growing literature on quantitative models of the spatial economy, including Eaton and Kortum (2002), Redding (2016), Tombe and Zhu (2019) and Fan (2019). While most of this research examines linkages across locations due to trade in goods and movement of labor, recent studies have emphasized linkages caused by consumption in more than one location (Albert and Monras, 2020; Miyauchi et al., 2021). Albert and Monras (2020) show that immigrants spend a large share of their income in their home countries, and their consumption is affected by prices both in the destination and home countries. They build a quantitative spatial equilibrium model to quantify the advantage of immigrants living in productive and expensive cities in the U.S. Similarly, our quantitative model also features consumption decisions based on prices in two locations, but they are made by migrants maximizing integral household utilities. We use the model to further study the impact of remittances on structural change and regional inequality.

Second, our work is related to the literature on the impact of remittances. The existing research has centered mainly on the micro-economic aspects, and we know little about their general equilibrium effects on income, welfare and sectoral composition. Four studies are most closely related to our paper. Acosta et al. (2009) and Chatterjee and Turnovsky (2018) link remittances to Dutch disease and the evolution of the informal economy, respectively. di Giovanni et al. (2015) finds that natives in the source regions benefit from migration through remittances. Much of this literature takes remittances as exogenous transfers, although factors like income and price variation may affect migrants' remittance behavior (Yang, 2011). In contrast, we model remittances as endogenous intra-household transfers and nest them into the spatial model to quantify their impacts.

Last but not least, our paper connects to the literature on structural change. Most of the earlier studies focus on direct forces including: technological progress, such as Gollin et al. (2002), Ngai and Pissarides (2007) and Alvarez-Cuadrado and Poschke (2011); international trade, for instance, Uy et al. (2013), Cravino and Sotelo (2019) and Fajgelbaum and Redding (2018); and migration costs, such as Lee and Wolpin (2006), Dekle and Vandenbroucke (2012) and Hao et al. (2020). We make two contributions to this line of literature. First, we explore remittances as a new driving force of structural change. Second, this study provides a new insight that any policy changes affecting migration, also have further impacts on structural change through remittances. Thus, ignoring remittances may bias the evaluation of such policies.

The remainder of the paper is organized as follows. Section 2 describes the facts about migrants' remittance behavior. We develop the quantitative framework for modeling endogenous remittances in Section 3. In Section 4, we discuss the data sources and calibrate our model to the Chinese economy in 2010. We then perform counterfactual analysis in Section 5, and conclude in Section 6. Additional details are arranged in the Online Appendix.

2 Facts About Migrants' Remittance Behavior

This section provides some stylized facts about migrants' remittance behavior in China using the China Migrants Dynamic Survey (CMDS) data. These facts also motivate some of our model assumptions and provide key moments for disciplining the model.

Since 2009, the National Health Commission of China conducts the CMDS and collects data on migrants aged 16 to 60 through a series of questionnaire-based interviews on a yearly basis. We focus on the wave of 2010, which covers 100 cities and 128,000 observations. We also perform regression analysis using the 2011 data because the later wave contains extra variables related to the migrants' remittance motives. More details of the data can be found in Online Appendix A.1.[2]

We first describe remittances and household joint migration patterns at the aggregate level. Among all surveyed migrants in 2010, 73% of them send remittances to home (the "remitters"). The total remittances are about 19% of the remitters' total income, and 14% of all migrants' income. 56% of surveyed households make a joint migration decision with at least two adult workers in the destination city, while the remaining household has only one migrant. Among the joint migration households, the majority (50% out of 56%) has two adult workers. We later develop a household migration model with internal transfers that matches the share of remittance in all migrants' income and the share of households moving out together.

Many factors affect migrants' remittance decisions, e.g., migrants' and remaining families' incomes (Rapoport and Docquier, 2006), and the living costs in the migration destination (Yang, 2011). We now examine these factors based on the survey data. In Panel A of Table 1, we regress migrants' remittances on their income, local expenditure, and the number of family members moving together in the 2010 data. We control for destination city fixed effects or destination city × home province (migrant's *Hukou* registered province) fixed effects and focus on

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[2] In an earlier version of the paper, we use micro data from the China Household Income Project (CHIP) to document migrants' remittance behavior. We prefer using CMDS here because it has a much larger sample and allows us to calculate migration and remittance behavior by migrant home provinces, which is used to validate our model later. We present regression evidence using CHIP in Online Appendix A.2 and find qualitatively similar results as Table 1. We also find that 68% of the migrants send remittances back for household consumption purposes, according to CHIP.

Table 1: Determinants of Remittances

Panel A: CMDS 2010	Dependent Variable					
	log(remittance)		log(1 + remittance)		$\mathbf{1}$(remittance $>$ 0)	
	(1)	(2)	(3)	(4)	(5)	(6)
log(Migrant's Income)	0.809^a	0.791^a	1.461^a	1.443^a	0.165^a	0.164^a
	(0.022)	(0.023)	(0.050)	(0.049)	(0.007)	(0.007)
log(Migrant's Expenditure)	-0.257^a	-0.249^a	-0.630^a	-0.586^a	-0.080^a	-0.073^a
	(0.017)	(0.017)	(0.039)	(0.039)	(0.006)	(0.006)
No. of Family Members Moving Together	-0.287^a	-0.281^a	-0.574^a	-0.578^a	-0.070^a	-0.072^a
	(0.008)	(0.008)	(0.016)	(0.016)	(0.003)	(0.003)
City FE	Yes		Yes		Yes	
Hukou Prov × City FE		Yes		Yes		Yes
Observations	77763	77356	119285	118904	120612	120230
R^2	0.221	0.245	0.129	0.151	0.075	0.096

Panel B: CMDS 2011	Dependent Variable					
	log(remittance)		log(1 + remittance)		$\mathbf{1}$(remittance $>$ 0)	
	(1)	(2)	(3)	(4)	(5)	(6)
log(Migrant's Income)	0.672^a	0.649^a	1.479^a	1.453^a	0.177^a	0.176^a
	(0.014)	(0.014)	(0.029)	(0.030)	(0.005)	(0.005)
log(Migrant's Expenditure)	-0.110^a	-0.088^a	-0.679^a	-0.627^a	-0.104^a	-0.098^a
	(0.012)	(0.013)	(0.028)	(0.029)	(0.004)	(0.005)
No. of Family Members Moving Together	-0.252^a	-0.242^a	-0.375^a	-0.371^a	-0.036^a	-0.037^a
	(0.005)	(0.006)	(0.012)	(0.012)	(0.002)	(0.002)
If need to support the old or children in the hometown	0.057^a	0.055^a	0.813^a	0.804^a	0.140^a	0.139^a
	(0.010)	(0.011)	(0.024)	(0.024)	(0.004)	(0.004)
If left-behind members lack money	0.026^b	0.027^b	0.115^a	0.106^a	0.018^a	0.016^a
	(0.011)	(0.011)	(0.024)	(0.025)	(0.004)	(0.004)
City FE	Yes		Yes		Yes	
Hukou Prov × City FE		Yes		Yes		Yes
Observations	89007	87852	127407	126227	127407	126227
R^2	0.242	0.275	0.130	0.158	0.091	0.117

Notes: The dependent variables are the log of remittances measured in Chinese Yuan (or one plus remittance values) or an indicator of whether the migrant sends remittances back to her/his home village. Panel A based on the data of 2010; Panel B is based on the data of 2011, since the information on migrants' hometowns is only available this year. City FE denotes the destination city fixed effect; Hukou Prov × City FE means the migrant's origin province (*Hukou* registered province) × destination city fixed effect. Robust standard errors are in parentheses. Significance levels: c 0.1, b 0.05, a 0.01.

variations across migrants within the same destination (or origin-destination pair). We find that remittances increase with migrants' income and decrease with their expenditure and the number of family members moving together to the same destination city, at both intensive and extensive margins. Focusing on the intensive margin (Columns 1-2), the elasticities of remittances with respect to migrants' income and expenditure are around 0.80 and -0.25, respectively. Moving together with one more family member lowers the remittances by around 28 log points.

We next evaluate how the need for income at home affects remittances. One challenge here is that we have limited information about migrants' family members at home in the survey. Fortunately, the 2011 survey asks two additional questions: whether the migrants need to support elders or children at home and whether their left-behind family members need income.

Therefore, we supplement our earlier analysis using the 2011 data and including these two indicator variables. We find that supporting elders or children at home increases remittances by 5.5 log points, while claiming that their left-behind family members need income is associated with a 2.7 log point increase in remittances (Panel B, Column 2 of Table 1). The results for the extensive margins are qualitatively similar to the intensive margins. The impacts of migrants' own income, expenditure and the number of family members moving together are similar to those estimated with the 2010 data in Panel A.

In sum, we find that remittances increase with migrants' income and decrease with migrants' living costs. Moreover, supporting the left-behind family members is an important motive for remittance. As discussed in Funkhouser (1995) and our model later, the evidence here is consistent with altruistically motivated remittances. We therefore model remittances as intra-household transfers to balance the consumption level of each household member (Stark et al., 1986).

3 The Model

In this section, we describe our model with household migration and intra-household transfers. There are $N+1$ regions in the economy, indexed by $n \in \{1, \dots, N+1\}$. These regions consist of N cities in China and one extra region representing the rest of the world (*RoW*). The set of the Chinese cities is denoted by $\mathcal{N}$. Each region has three sectors: agriculture (A), manufacturing (M) and services (S), denoted by $j \in \{A, M, S\}$. Agriculture and manufacturing goods are tradable, while services are not. Labor and land are the two primary factors of production. There are $\bar{F}_n$ households with a *Hukou* registration in each city n, and each household has two workers who supply their labor inelastically. Workers can move across cities within China (subject to migration costs), but not internationally. $\bar{L}_{N+1}$ is the total employment in *RoW*. Each region is endowed with H_n units of land.

3.1 Consumer Preferences

The preference of a consumer ω residing in region n depends on the consumption of composite final goods in the three sectors, $c_n^j, j \in \{A, M, S\}$. Given consumers' income v and prices of the composite final goods $\mathbf{P_n} \equiv \{P_n^j\}_{j\in\{A,M,S\}}$, consumers solve the following problem:

$$u(v, \mathbf{P_n}) \equiv \max_{c_n^j} \left[\sum_{j\in\{A,M,S\}} (\alpha^j)^{\frac{1}{\varsigma}} \left(c_n^j(\omega) + \bar{c}^j \right)^{\frac{\varsigma-1}{\varsigma}} \right]^{\frac{\varsigma}{\varsigma-1}} \quad s.t. \quad \sum_j P_n^j c_n^j \leq v, \tag{1}$$

where $u(v, \mathbf{P_n})$ is the indirect utility function of the consumption problem. The coefficients α^j are non-negative weights that add up to one, and ς governs the elasticity of substitution between goods in different sectors; $\bar{c}^j$ are constants. We use $\mathcal{J}$ to denote the set of sectors, i.e. $\mathcal{J} = \{A, M, S\}$.

As is seen from the utility function, we follow Herrendorf et al. (2013) and Kehoe et al. (2018) and adopt the non-homothetic Stone-Geary preferences to allow for income effects on structural change.[3] Specifically, we assume $\bar{c}^M$ to be zero but allow $\bar{c}^A$ and $\bar{c}^S$ to be different from zero. If $\bar{c}^j < 0$, the consumer has a subsistence requirement in goods j. Only if the subsistence consumption of goods j is satisfied, will the consumer be willing to consider trade-offs between goods j and others. If $\bar{c}^j > 0$, it indicates that the consumer has an endowment in goods j, say, because of household production. If all $\bar{c}^j$ equal zero, the function reduces to the usual CES utility function. In our calibration, we find $\bar{c}^A < 0$ and $\bar{c}^S > 0$, consistent with the literature.

Solving the consumer's optimization problem, we obtain the following expression of indirect utility, $u(v, \mathbf{P}_n)$,

$$u(v, \mathbf{P}_n) = \frac{v + \sum_{j \in \mathcal{J}} P_n^j \bar{c}^j}{P_n}, \tag{2}$$

where $P_n = \left[\sum_{j \in \mathcal{J}} \alpha^j \left(P_n^j\right)^{1-\varsigma}\right]^{\frac{1}{1-\varsigma}}$. Denoting the per capita income in region n as $\bar{v}_n$, we can derive the share of consumption in sector j goods as

$$S_n^j = \alpha^j \left(\frac{P_n^j}{P_n}\right)^{1-\varsigma} + \frac{\alpha^j \left(\frac{P_n^j}{P_n}\right)^{1-\varsigma} \sum_{j \in \mathcal{J}} P_n^j \bar{c}^j - P_n^j \bar{c}^j}{\bar{v}_n}. \tag{3}$$

These expenditure shares imply that either a subsistence requirement ($\bar{c}^j < 0$) or an endowment ($\bar{c}^j > 0$) is driving the income effect. (see Online Appendix B.1 for the derivation of aggregate expenditure shares) As income grows, the share allocated to the goods of which the consumer has a subsistence requirement will decrease, and the share allocated to the goods of which the consumer has an endowment will increase.

3.2 Production and Trade

Final goods within each sector are composites of a continuum of horizontally differentiated varieties h. The production technology of Q_n^j is a CES aggregator of quantities of each variety

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[3] In Online Appendix D.1, we consider the Price Independent Generalized Linearity (PIGL) preference similar to that in Hao et al. (2020) and Boppart (2014). Our main quantitative predictions are similar under the alternative demand system.

$q_n^j(h)$

$$Q_n^j = \left[\int_0^1 q_n^j(h)^{\frac{\sigma-1}{\sigma}} dh\right]^{\frac{\sigma}{\sigma-1}},$$

where σ is the elasticity of substitution across varieties. The CES composite good is used both for consumption and as intermediate inputs.

A producer with productivity $z_n^j(h)$ produces variety h using the following Cobb-Douglas technology

$$q_n^j(h) = z_n^j(h) \left(\frac{l_n^j(h)}{\beta^j}\right)^{\beta^j} \left(\frac{h_n^j(h)}{\eta^j}\right)^{\eta^j} \prod_{k\in\mathcal{J}} \left(\frac{m_n^{j,k}(h)}{\gamma^{jk}}\right)^{\gamma^{jk}},$$

where $l_n^j(h)$ is the labor, $h_n^j(h)$ is the land, and $m_n^{j,k}(h)$ are the composite intermediate goods from sector k used for the production of variety h; β^j and η^j are labor and land shares, and γ^{jk} is the share for intermediate input from sector k. We assume constant returns to scale, therefore $\beta^j + \eta^j + \sum_{k\in\mathcal{J}} \gamma^{jk} = 1$.

The marginal cost for a firm with productivity z is

$$c_n^j(z) = \frac{(w_n^j)^{\beta^j} (r_n)^{\eta^j} \prod_{k\in\mathcal{J}} (P_n^k)^{\gamma^{jk}}}{z}, \tag{4}$$

where w_n^j and r_n denote the location-sector specific wage and the location-specific rental rates, respectively; P_n^k is the price of intermediate input from sector k. To simplify notations, we denote the numerator of equation (4) with c_n^j, i.e., $c_n^j = (w_n^j)^{\beta^j} (r_n)^{\eta^j} \prod_{k\in\mathcal{J}} (P_n^k)^{\gamma^{jk}}$.

We assume that productivity z is independently drawn across sectors and regions from a Fréchet distribution:

$$F_n^j(z) = e^{-A_n^j z^{-\theta}},$$

where A_n^j governs the average productivity of sector j in region n; the shape parameter θ determines the dispersion of productivity across goods within sector j. Therefore, the price of variety h produced in region n and transported to region i is given by

$$p_{ni}^j(h) = \frac{\tau_{ni}^j c_n^j}{z_n^j(h)},$$

where τ_{ni}^j is the iceberg trade cost from n to i. The consumers in region i purchase each variety h provided by the lowest-cost supplier. As Eaton and Kortum (2002) demonstrate, the above price equation together with the Fréchet productivity distribution implies that the equilibrium share of region n's total expenditure on sector j's goods produced in region i is

$$\pi_{ni}^j = \frac{A_i^j \left(\tau_{ni}^j c_i^j\right)^{-\theta}}{\sum_{s=1}^N A_s^j \left(\tau_{ns}^j c_s^j\right)^{-\theta}}. \tag{5}$$

The price of the composite final goods is

$$P_n^j = \gamma \left[\sum_{i=1}^{N} A_i^j \left(\tau_{ni}^j c_i^j \right)^{-\theta} \right]^{-\frac{1}{\theta}} = \gamma (A_n^j)^{-\frac{1}{\theta}} (\pi_{nn}^j)^{\frac{1}{\theta}} c_n^j, \tag{6}$$

where $\gamma \equiv \left[\Gamma \left(\frac{\theta+1-\sigma}{\theta} \right) \right]^{\frac{1}{1-\sigma}}$ and $\Gamma(\cdot)$ denotes the Gamma function. Note that equation (6) can also be applied to service goods, which is a special case with $\tau_{ni}^S = \infty, \forall n \neq i$ and $\pi_{nn}^S = 1$.

3.3 Internal Migration and Remittances

To potential barriers in rural-to-urban migration, we distinguish between households with rural and urban *Hukou* types, and divide each city into a rural labor market (the agricultural sector) and an urban labor market (manufacturing and services sectors). Each city is endowed with $\bar{F}_n^{\mathcal{R}}$ rural households and $\bar{F}_n^{\mathcal{U}}$ urban households, and rural (urban) households initially work in the rural (urban) labor market. Similar to Tombe and Zhu (2019) and Fan (2019), we assume an extra migration cost for workers who migrate from rural to urban labor markets. We define a worker as a migrant if he/she moves out of the home city (cross-city migration) or if he/she has a rural *Hukou* but works in the urban labor market in the home city (within-city migration).

3.3.1 Household Utility and Remittance

To incorporate the altruistic motive of remittances and keep the spatial model as simple as possible, we introduce the household as the basic unit and consider the decisions of family members within each household. Specifically, based on the average family size in China, we assume that each household has three members: two working-age adults (Member 1 and Member 2) and one dependent (Member 3).[4] Member 2 can migrate within the country while Member 1 can either stay at home or move together with Member 2;[5] Member 3 can only stay in the hometown and rely on transfers from other family members as the source of income. City-sector migration decisions are made to maximize the integral household utility.

Following the spirit of Rapoport and Docquier (2006), we express the household indirect utility function (before applying migration costs and preference shocks) as:

$$\tilde{U}_{o,ni}^{kj} = [u(I_1 - T_1, \mathbf{P_n})]^{\lambda_1} [u(I_2 - T_2, \mathbf{P_i})]^{\lambda_2} [u(I_3 + T_1 + T_2, \mathbf{P_o})]^{\lambda_3}. \tag{7}$$

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[4] According to China Statistical Year Book, the average household size is 3.10 in 2010. Multiplied by the share of the population from age 20 to 60, which is 0.66, the average number of working-age members in each household is 2.1.

[5] We restrict the location of Member 2 to simplify the household problem and reduce the computational burden. In addition, we are not aware of any data on the share of households with two adults migrating to *different* cities, so we cannot discipline such "separate migration" with data. In light of the large separation cost that we estimate in Section 4, the share of such households is likely to be small in reality.

For simplicity, we suppress the notation for household *Hukou* type and only focus on the indirect utility (not taking into account idiosyncratic preference shock and migration cost) here. The first subscript o of $U^{kj}_{o,ni}$ denote the hometown of this household, and n and i denote the working locations of Members 1 and 2, respectively; the superscript k and j are the sectors where Members 1 and 2 work, respectively. The parameters λ_1, λ_2 and λ_3 denote the weights of Members 1, 2 and 3 in the entire household utility, and $\lambda_1+\lambda_2+\lambda_3=1$. I_1, I_2 and I_3 are the pre-transfer income for three members;[6] T_1 and T_2 are the amount of transfers from Members 1 and 2 to Member 3, respectively.

Optimal Remittance Conditional on the location and sector choices of Members 1 and 2, these two members simultaneously decide their amounts of intra-household transfers to solve the following optimization problem

$$\max_{T_1,T_2} u(I_1-T_1,\mathbf{P_1})^{\lambda_1}u(I_2-T_2,\mathbf{P_2})^{\lambda_2}u(I_3+T_1+T_2,\mathbf{P_3})^{\lambda_3}, \tag{8}$$

subject to $T_1+T_2\geq 0$ if Member 1 and 2 stay in the same place; $T_1+T_2\geq 0$ and $T_2\geq 0$ if Member 2 migrates alone.[7] These restrictions on T_1,T_2 ensure that the direction of the transfers must be from the migrants to the non-migrants, but at the same time allows the possibility of transfers between two migrants. First, when Members 1 and 2 migrate together, $T_1+T_2\geq 0$ ensures that the dependent receives non-negative transfers. Both members can transfer money to support the dependent. It is also possible that T_1 or T_2 is negative, meaning that the highest income person effectively transfers to the other two household members. Remittances within the household are T_1+T_2. Second, when Member 2 migrates alone, we restrict $T_2\geq 0$, but it is possible that Member 1 also gives transfer to the dependent ($T_1>0$). Member 1's transfers, however, are not counted as remittances since he/she does not migrate. It is also possible that Member 1 receives transfers from Member 2, i.e., $T_1<0$. Whether T_1 is positive or negative, the total remittance in the household is T_2 in this case. Finally, when neither Members 1 nor 2 migrate, we still allow household-utility-maximizing transfers T_1 and T_2, though we do not count these local transfers as remittances when calibrating our model to the data.

Solving the optimization problem in equation (8) under different migration scenarios, we obtain the following characterization of optimal remittances:

Proposition 1. *Conditional on the location and sector choices of Member 1 and Member 2, the optimal transfers under different household migration situations are as follows:*

1. *When Member 1 and Member 2 stay at the same place.*

---

[6] Note that the "income" here includes a term due to the Stone-Geary preference. In particular, $I_k\equiv\nu_k+\sum_{j\in\mathcal{J}}P^j\bar{c}^j$, where ν_k is the labor and land income of Member k. This is also the numerator of equation (2).

[7] For notational simplicity, we suppress the subscripts and superscripts for location and sector here and only use the number $\{1,2,3\}$ to identify the type of family member.

   (a) *If* $I_1 + I_2 \geq (\lambda_1 + \lambda_2)(I_1 + I_2 + I_3)$,

$$T_1^* = (1 - \lambda_1)I_1 - \lambda_1 I_2 - \lambda_1 I_3; \quad T_2^* = (1 - \lambda_2)I_2 - \lambda_2 I_1 - \lambda_2 I_3;$$

   (b) *Else,*

$$T_1^* = \frac{\lambda_2 I_1 - \lambda_1 I_2}{\lambda_1 + \lambda_2}; \quad T_2^* = \frac{\lambda_1 I_2 - \lambda_2 I_1}{\lambda_1 + \lambda_2}.$$

2. *When Member 2 migrates alone.*

   (a) *If* $I_1 + I_2 \geq (\lambda_1 + \lambda_2)(I_1 + I_2 + I_3)$ *and* $I_2 \geq \lambda_2(I_1 + I_2 + I_3)$,

$$T_1^* = (1 - \lambda_1)I_1 - \lambda_1 I_2 - \lambda_1 I_3; \quad T_2^* = (1 - \lambda_2)I_2 - \lambda_2 I_1 - \lambda_2 I_3.$$

   (b) *If* $I_2 \leq \lambda_2(I_1 + I_2 + I_3)$, *while* $I_1 \geq \frac{\lambda_1}{\lambda_1 + \lambda_3}(I_1 + I_3)$,

$$T_1^* = \frac{\lambda_3 I_1 - \lambda_1 I_3}{\lambda_1 + \lambda_3}; \quad T_2^* = 0.$$

   (c) *If* $I_1 + I_2 \leq (\lambda_1 + \lambda_2)(I_1 + I_2 + I_3)$, *and* $I_2 \geq \frac{\lambda_2}{\lambda_1 + \lambda_2}(I_1 + I_2)$,

$$T_1^* = \frac{\lambda_2 I_1 - \lambda_1 I_2}{\lambda_1 + \lambda_2}; \quad T_2^* = \frac{\lambda_1 I_2 - \lambda_2 I_1}{\lambda_1 + \lambda_2}.$$

   (d) *If* $I_1 \leq \frac{\lambda_1}{\lambda_1 + \lambda_3}(I_1 + I_3)$ *and* $I_2 \leq \frac{\lambda_2}{\lambda_1 + \lambda_2}(I_1 + I_2)$

$$T_1^* = 0; \quad T_2^* = 0.$$

These optimal remittance formula in Proposition 1 imply the following corollary:

Corollary 1. *The optimal transfers* T_1^*, T_2^* *are weakly increasing in the income of the focal family member and weakly decreasing in the income of the other members. They are weakly decreasing in the utility weight of the focal family member and are weakly increasing in the weights of the other family members.*

The proofs of Proposition 1 and Corollary 1 are relegated to Appendix B. When the inequality constraints on T_1, T_2 are not binding, optimal intra-household redistribution simply makes each member's post-transfer income proportional to their utility weights. Although the form of optimal transfers depends on the household migration pattern, it is straightforward that the transfers increase with the sender's income and the recipient's utility weight, and decrease with the recipient's income and the sender's own utility weight.

3.3.2 Income of Workers

Each region is endowed with a fixed amount of land. Following Tombe and Zhu (2019), we assume land revenue is distributed equally to local residents, and thus migrant workers have no claims to land revenue. Given the fixed land endowment H_n, and the Cobb-Douglas production technology, the expenditure on land in region n, sector j, is therefore

$$r_n H_n^j = \frac{\eta^j}{\beta^j} w_n^j L_n^j, \tag{9}$$

where L_n^j is the equilibrium labor employed in sector j and location n.

Specifically, local rural residents receive the land income from the rural sector, and local urban residents receive the land income from the urban sector (manufacturing and services). The migrant worker only receives wages. Therefore, the pre-transfer income for a rural worker from region o working in region d and industry j is given by:

$$I_{od}^{\mathcal{R},j} = \begin{cases} w_o^A + \dfrac{\eta^A}{\beta^A} \dfrac{w_o^A L_o^A}{N_o^{\mathcal{R}}}, & \text{if } d = o \text{ and } j = A, \\ w_d^j, & \text{if } d \neq o \text{ or } j \neq A, \end{cases}$$

where the first superscript $\mathcal{R}$ of $I_{od}^{\mathcal{R},j}$ denotes the worker's rural *Hukou* status; and $N_o^{\mathcal{R}}$ is the number of local rural residents, which equals the total number of all dependents (Member 3) born in region o with a rural *Hukou* and working-age adults (Members 1 and 2) who do not migrate.[8] The pre-transfer income for a worker with urban *Hukou* is given by:

$$I_{od}^{\mathcal{U},j} = \begin{cases} w_o^j + \displaystyle\sum_{k \in \{M,S\}} \dfrac{\eta^k}{\beta^k} \dfrac{w_o^k L_o^k}{N_o^{\mathcal{U}}}, & \text{if } d = o \text{ and } j \neq A, \\ w_d^j, & \text{if } d \neq o \text{ or } j = A, \end{cases}$$

where $N_o^{\mathcal{U}}$ is the number of local urban residents, which equals the total number of all dependents born in region o with an urban *Hukou* and working-age adults who do not migrate. As a local resident, Member 3 can also receive land income. The pre-transfer income for Member 3

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[8] Though migrant workers do not have claims to land income at home, they still benefit from the fact that the other household members will have income from land ownership, which can reduce the demand for remittances. This is a subtle difference between our model and other one-person household models that make the same assumptions about land income claims.

with rural or urban *Hukou* is

$$I_o^{\mathcal{H}} = \begin{cases} \dfrac{\eta^A}{\beta^A} \dfrac{w_o^A L_o^A}{N_o^{\mathcal{R}}}, & \text{if } \mathcal{H} = \mathcal{R}, \\ \displaystyle\sum_{k \in \{M,S\}} \dfrac{\eta^k}{\beta^k} \dfrac{w_o^k L_o^k}{N_o^{\mathcal{U}}}, & \text{if } \mathcal{H} = \mathcal{U}. \end{cases}$$

3.3.3 Internal Migration

The complete utility function for a household come from region o with *Hukou* type $\mathcal{H} \in \{\mathcal{R}, \mathcal{U}\}$ is as follows:

$$U_{o,ni}^{\mathcal{H},kj} = \frac{b_{ni}^{kj}}{\kappa_{ni}(\mu_{on}^{\mathcal{H},k})^{\lambda_1}(\mu_{oi}^{\mathcal{H},j})^{\lambda_2}} [u(I_{on}^{\mathcal{H},k} - T_{1o,ni}^{\mathcal{H},kj}, \mathbf{P_n})]^{\lambda_1} [u(I_{oi}^{\mathcal{H},j} - T_{2o,ni}^{\mathcal{H},kj}, \mathbf{P_i})]^{\lambda_2} [u(I_o^{\mathcal{H}} + T_{o,ni}^{\mathcal{H},kj}, \mathbf{P_o})]^{\lambda_3}, \tag{10}$$

where b_{ni}^{kj} is the idiosyncratic household preference over locations and sectors, and we assume that it is drawn from a Fréchet distribution with a cumulative distribution function $F_{ni}^{kj}(b) = e^{-B_{ni}^{kj} b^{-\epsilon}}$.[9] Moreover, the household will face an extra separation cost if Members 1 and 2 stay in two different cities, caputred by the term κ_{ni}. We set $\kappa_{ni} = 1$ if $n = i$ while $\kappa_{ni} = \kappa > 1$ if $n \neq i$. The total transfer that Member 3 received from the other two members is $T_{o,ni}^{\mathcal{H},kj} = T_{1o,ni}^{\mathcal{H},kj} + T_{2o,ni}^{\mathcal{H},kj}$. $\mu_{oi}^{\mathcal{H},j} \geq 1$ is the iceberg migration cost for a worker with *Hukou* type $\mathcal{H}$ to move from o to i and work in sector j. In our calibration, we allow the individual migration costs, $\mu_{on}^{\mathcal{H},k}$ and $\mu_{oi}^{\mathcal{H},j}$, to depend on both the characteristics of the city pairs (such as distances) and whether the worker migrates from a rural to an urban labor market, captured by the superscripts $(\mathcal{H}, k)$ and $(\mathcal{H}, j)$.

Members 1 and 2 make the migration decision jointly to maximize the household integral utility. We restrict the choice set of locations (n, i) by assuming that Member 1 can either stay or migrate to the same labor market with Member 2 (see Footnote 5). We use $m_{o,ni}^{\mathcal{R},kj}$ to denote the share of rural households in location o with Member 1 working in location n and sector k, and Member 2 working in location i and sector j. Similarly, the migration share of urban households is denoted by $m_{o,ni}^{\mathcal{U},kj}$. Given the indirect utility $u(\cdot)$, migration costs $\mu_{on}^{\mathcal{H},k}$, separation cost κ_{ni}, and the Fréchet distribution of idiosyncratic preference shocks, the migration shares can be expressed as

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[9] We thank an anonymous referee for the suggestion of applying the idiosyncratic preference shock to the integral household utility instead of having individual-specific preference shocks. It is well known that the product of two Fréchet shocks does not have a Fréchet distribution. The setup here makes the household's joint migration problem tractable. Antras and de Gortari (2020) make a similar assumption when modeling global value chains, in which they assume the "chain-level" shocks follow a Fréchet distribution.

$$m_{o,ni}^{\mathcal{H},kj} = \frac{B_{ni}^{kj}\left(\frac{u_{o,ni}^{\mathcal{H},kj}}{\kappa_{ni}(\mu_{on}^{\mathcal{H},k})^{\lambda_1}(\mu_{oi}^{\mathcal{H},j})^{\lambda_2}}\right)^{\epsilon}}{\sum_{k',j'\in\mathcal{J}}\sum_{n',i'\in\mathcal{N}} B_{n'i'}^{k'j'}\left(\frac{u_{o,n'i'}^{\mathcal{H},k'j'}}{\kappa_{n'i'}(\mu_{on'}^{\mathcal{H},k'})^{\lambda_1}(\mu_{oi'}^{\mathcal{H},j'})^{\lambda_2}}\right)^{\epsilon}}, \tag{11}$$

where the household indirect utility $u_{o,ni}^{\mathcal{H},kj}$ can be calculated from equations (2) and (7) as

$$u_{o,ni}^{\mathcal{H},kj} = \frac{\left(I_{on}^{\mathcal{H},k} - T_{1o,ni}^{\mathcal{H},kj} + \sum_{s\in\mathcal{J}} P_n^s \bar{c}^s\right)^{\lambda_1}\left(I_{oi}^{\mathcal{H},j} - T_{2o,ni}^{\mathcal{H},kj} + \sum_{s\in\mathcal{J}} P_i^s \bar{c}^s\right)^{\lambda_2}\left(I_o^{\mathcal{H}} + T_{o,ni}^{\mathcal{H},kj} + \sum_{s\in\mathcal{J}} P_o^s \bar{c}^s\right)^{\lambda_3}}{(P_n)^{\lambda_1}(P_i)^{\lambda_2}(P_o)^{\lambda_3}}.$$

For migration patterns that violate the migration restrictions on Member 1 (i.e., migrating to a different labor market from that of Member 2), we simply set $u_{o,ni}^{\mathcal{H},kj} = 0$ so that these patterns will never be chosen by any family.

The total number of workers in region n and sector j is

$$\begin{aligned} L_n^j = &\sum_{\mathcal{H}\in\mathcal{U},\mathcal{R}} \bar{F}_n^{\mathcal{H}} \sum_{i\in\mathcal{N}}\sum_{k\in\mathcal{J}} m_{n,ni}^{\mathcal{H},jk} + \sum_{\mathcal{H}\in\mathcal{U},\mathcal{R}}\sum_{o\neq n} \bar{F}_o^{\mathcal{H}} \sum_{k\in\mathcal{J}} m_{o,nn}^{\mathcal{H},jk} \\ &+ \sum_{\mathcal{H}\in\mathcal{U},\mathcal{R}}\sum_{o\in\mathcal{N}} \bar{F}_o^{\mathcal{H}} \sum_{k\in\mathcal{J}} m_{o,on}^{\mathcal{H},kj} + \sum_{\mathcal{H}\in\mathcal{U},\mathcal{R}}\sum_{o\neq n} \bar{F}_o^{\mathcal{H}} \sum_{k\in\mathcal{J}} m_{o,nn}^{\mathcal{H},kj} \end{aligned} \tag{12}$$

The employment in region n and sector j includes four components, corresponding to the four terms on the right-hand side of equation (12): (1) the number of Member 1 type workers staying in their hometowns; (2) the number of Member 1 type workers moving together to region n with Member 2 and working in sector j; (3) the number of Member 2 type workers working in region n and sector j whose partners stay in the hometown; (4) the number of Member 2 type workers working in region n and sector j with Member 1 moving together.

Correspondingly, the migration flow L_{od} for $o \neq d$ can be expressed as

$$L_{od} = \sum_{\mathcal{H}\in\mathcal{U},\mathcal{R}} \bar{F}_o^{\mathcal{H}} \sum_{k,j\in\mathcal{J}} m_{o,dd}^{\mathcal{H},jk} + \sum_{\mathcal{H}\in\mathcal{U},\mathcal{R}} \bar{F}_o^{\mathcal{H}} \sum_{n\in\{o,d\}}\sum_{k,j\in\mathcal{J}} m_{o,nd}^{\mathcal{H},jk}.$$

The first component is the number of Member 1 type workers who migrate together with Member 2; the second part is the number of Member 2 type workers who migrate to region d. Then, the number of workers staying in the home region L_{oo} is

$$L_{oo} = \sum_{\mathcal{H}\in\mathcal{U},\mathcal{R}} \bar{F}_o^{\mathcal{H}} \sum_{d\in\mathcal{N}}\sum_{k,j\in\mathcal{J}} m_{o,od}^{\mathcal{H},jk} + \sum_{\mathcal{H}\in\mathcal{U},\mathcal{R}} \bar{F}_o^{\mathcal{H}} \sum_{k,j\in\mathcal{J}} m_{o,oo}^{\mathcal{H},jk},$$

where the first part is the number of Member 1 type workers staying in the home region; the second part is the number of Member 2 type workers staying in the home region. We define the bilateral migration share, m_{od}, as

$$m_{od} = \frac{L_{od}}{\sum_{d' \in \mathcal{N}} L_{od'}}, \tag{13}$$

where the numerator is the number of workers from region o working in region d, and the denominator is the total number of workers from region o.

3.4 General Equilibrium

The total revenue of sector j in region n is

$$R_n^j = \sum_{i=1}^{N} \pi_{in}^j X_i^j, \tag{14}$$

where π_{in}^j is the trade share as in equation (5), and X_i^j is the total absorption/expenditure of sector j in region i. Total absorption includes the demand for composite intermediates by producers as well as the demand for final goods by consumers. Therefore,

$$X_n^j = S_n^j \bar{v}_n L_n + \sum_{k \in \mathcal{J}} \gamma^{kj} R_n^k, \tag{15}$$

where $\bar{v}_n$ is the average income in region n net of cross-region remittances; L_n is the total population in region n. Total income post remittance transfers of region n becomes

$$\begin{aligned} \bar{v}_n L_n = & \sum_{k \in \mathcal{J}} w_n^k L_n^k + \sum_{k \in \mathcal{J}} \frac{\eta^k}{\beta^k} w_n^k L_n^k - \sum_{\mathcal{H} \in \mathcal{U},\mathcal{R}} \sum_{o \neq n} \bar{F}_o^{\mathcal{H}} \sum_{k,j \in \mathcal{J}} m_{o,on}^{\mathcal{H},jk} T_{2o,on}^{\mathcal{H},jk} - \sum_{\mathcal{H} \in \mathcal{U},\mathcal{R}} \sum_{o \neq n} \bar{F}_o^{\mathcal{H}} \sum_{k,j \in \mathcal{J}} m_{o,nn}^{\mathcal{H},jk} T_{o,on}^{\mathcal{H},jk} \\ & + \sum_{\mathcal{H} \in \mathcal{U},\mathcal{R}} \bar{F}_n^{\mathcal{H}} \sum_{d \neq n} \sum_{k,j \in \mathcal{J}} m_{n,nd}^{\mathcal{H},jk} T_{2n,nd}^{\mathcal{H},jk} + \sum_{\mathcal{H} \in \mathcal{U},\mathcal{R}} \bar{F}_n^{\mathcal{H}} \sum_{d \neq n} \sum_{k,j \in \mathcal{J}} m_{n,dd}^{\mathcal{H},jk} T_{n,dd}^{\mathcal{H},jk}. \end{aligned}$$

The first and second terms indicate the total labor and land income, respectively. The third and fourth components are the remittances sent out by migrants in region n, i.e., Member 2 migrating alone and Member 1 and 2 moving together to region n. The last two components are the remittances that region n receives from Member 2 migrating out alone and Member 1 and 2 moving out together.

Definition 1. Given the above exogenous parameters and endowments, a competitive equilibrium of the economy is defined as a set of prices and allocations such that the following conditions are satisfied:

a) expenditure shares across sectors follow equation (3) while the trade shares are given by equation (5);
b) migrants make their optimal remittance decisions according to Proposition 1;

c) migration shares for the household satisfy equation (11);

d) labor markets clear, i.e., $w_n^j L_n^j = \beta_j R_n^j$ for every n, j;

e) land markets clear, i.e., equation (9) holds for every n;

f) goods markets clear in each location and sector, i.e., equation (14) and (15) are satisfied.

4 Calibration

Before applying our model to conduct counterfactual experiments, we calibrate it to the equilibrium of the Chinese economy in 2010. Our sample includes 284 cities with complete data, covering over 99% of the total GDP in China in 2010. This section starts with a description of data sources and then describes the steps to calibrate the model parameters.

4.1 Data Description

For our analysis, we need data on internal migration, migrants' remittance behavior, internal and international trade, and prefecture-level social-economic statistics in China. We briefly discuss the data sources here.

We use the 2010 Population Census to construct migration flows between different labor markets, including rural-to-urban migration. The census provides detailed information on each individual's employment status, current city, current industry, the city of *Hukou* registration (home city) and the *Hukou* type (rural or urban). We use this information to determine each individual's migration status according to the following procedures. First, we restrict the sample to those aged 16 to 60, dropping workers above the official retirement age. Next, we exclude those who are not working, unless the reason for not working is either "on vacation" or "on sick leave".[10] We then classify a worker as a migrant if he or she is not working in the home city, or in the home city but not the same labor market as the *Hukou* type. For example, a manufacturing or service worker with a rural *Hukou* is counted as a migrant, even if he or she works in the home city. We refer to the current city/sector as the destination city/sector henceforth.

Using the 2010 inter-regional 30-industry input-output table, we calculate the trade flows between Chinese provinces. Based on China's GB2002 classification system, we assign each industry to one of the three sectors in our model. For any sector, the goods shipped from province o to province d includes goods for both intermediate input use and final consumption. Trade shares π_{do}^j are defined as the ratio of the value of goods j that shipped from province o to d to the total absorption in sector j, province d.

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[10] Information about the "current industry" is still available for workers who are on vacation or sick leave.

As discussed in Section 2, we obtain information on migrants' remittances and migration behavior from the China Migrants Dynamic Survey (CMDS), which we describe in Section 2. In particular, we use two moments, the share of remittances in total migrants' income and the fraction of households with at least two members migrating together, as our calibration targets.

Other social-economic variables, including each city's land endowments, city-industry level GDP, province-industry level consumer expenditure shares and the number of households in each labor market, are sourced from the China Statistical Yearbooks. We aggregate the 2010 Census micro data to obtain the city-level sectoral employment shares. However, the city-sector level wage data is only available from the 2005 mini Census. We infer the city-industry level wage in 2010 combining the 2005 city-industry level wage and the city-level average wage growth rate (2005 to 2010) calculated from the China City Statistical Yearbook.

4.2 Calibration and Estimation Strategies

We calibrate and estimate model parameters in three groups: (1) parameters that are directly obtained from the literature or observed in the data; (2) parameters that are estimated by inverting part of the model; (3) parameters that are estimated by solving the full model and matching data moments. We discuss the calibration and estimation strategies for each group of parameters. We present the values of parameters in the first group in this section and discuss the estimation results of the other two groups in the next section.

4.2.1 Parameters Calibrated Independently

Four parameters are taken from the existing literature. First, we set elasticity of substitution in the CES aggregator for final goods, σ, to 4, according to Bernard et al. (2003). Second, the Fréchet shape parameter for productivity determines the elasticity of trade flows to trade costs. We set $\theta = 4$, the same value used in Simonovska and Waugh (2014) and Tombe and Zhu (2019). Since $\theta > \sigma - 1$, we ensure that the integral of the price index will converge. Third, the Fréchet shape parameter for preference shock distribution, ϵ, corresponds to the elasticity of migration with respect to consumption utilities and iceberg migration costs. We set $\epsilon = 1.5$, which is in line with the estimates using Chinese data in Tombe and Zhu (2019). We set the elasticity of substitution between different consumption categories to 0.85, the value used in Herrendorf et al. (2013) and Kehoe et al. (2018). The shares of different inputs in production, $\{\beta^j, \eta^j, \gamma^{jA}, \gamma^{jM}, \gamma^{jN}\}$, are calibrated to the 2010 national input-output table (see Appendix C.1 for details). Table 2 summarizes the values and descriptions of these parameters.

Table 2: Parameters Calibrated Independently

Parameter	Value	Description	Source
σ	4	Elasticity of substitution across varieties within a sector	Bernard et al. (2003)
θ	4	Dispersion of productivities in the Fréchet distribution	Simonovska and Waugh (2014)
ϵ	1.5	Dispersion of amenities in the Fréchet distribution	Tombe and Zhu (2019)
ς	0.85	Elasticity of substitution between consumption categories	Herrendorf et al. (2013)
$\beta^A, \beta^M, \beta^S$	0.28, 0.10, 0.34	Output elasticity of labor in each sector	2010 Chinese National Input-output Table
η^A, η^M, η^S	0.29, 0.02, 0.05	Output elasticity of land in each sector	Tombe and Zhu (2019)
$\{\gamma^{jk}\}$	Appendix C.1	Input shares	2010 Chinese National Input-output Table

4.2.2 Parameters Estimated by Inverting Part of the Model

Trade Costs and Productivities We parameterize the trade costs following the gravity literature in international trade. Equation (16) specifies the trade costs between any two regions within China as a log-linear function of geographical characteristics and distances:

$$\log \tau_{od}^j = \sum_{i=1}^{4} \beta_i^\tau \times I_i + \sum_{i=1}^{3} \beta_{4+i}^\tau \times I_i \times Dist_{od}, \tag{16}$$

where I_1 to I_3 are mutually exclusive dummy variables: I_1 indicates whether o and d belong to different cities within the same province; I_2 indicates whether o and d belong to two different provinces within the same large region[11]; I_3 equals one if o and d belong to different large regions. I_4 indicates whether o and d share a provincial boundary. $Dist_{od}$ is the great-circle distance between o and d.

Similar to Fan (2019), we model the trade cost between a Chinese city o and the *RoW* as the sum of two components: the trade cost between that city and its nearest coastal port city, $p(o)$, and a sector-specific parameter, t^j, which captures all the barriers to international trade:

$$\log \tau_{o,RoW}^j = \log \tau_{o,p(o)}^j + t^j, \text{ if } o \neq RoW. \tag{17}$$

Note that we assume the internal trade costs are only source-destination specific, i.e. $\tau_{od}^A = \tau_{od}^M$ for $o, d \neq RoW$.

We jointly calibrate trade costs and regional productivity. The procedure consists of two steps. In the outer loop, we choose $\{\beta_j^\tau\}$ and $\{t^A, t^M\}$ such that the model-predicted bilateral trade flows are closest to the data counterparts. Since the model is at the city level and trade flow data are only available at the province level, we aggregate the model-predicted trade flows to the province level before comparing them to the data. Therefore, the problem in the outer

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[11] There are seven large regions in China: North (Beijing, Tianjin, Hebei, Shanxi and Inner Mongolia); Northeast (Heilongjiang, Jilin and Liaoning); East (Shanghai, Jiangsu, Zhejiang, Anhui, Jiangxi, Shandong and Fujian); Central (Henan, Hubei and Hunan); South (Guangdong, Guangxi and Hainan); Southwest (Chongqing, Sichuan, Yunan and Tibet); Northwest (Shaanxi, Gansu, Qinghai, Ningxia and Xinjiang).

loop is

$$\min_{\beta^\tau, t^j} \sum_{p,q \in \mathcal{P}} \left[\log\left(X_{p,q}^{Data}\right) - \log\left(\sum_{o \in p, d \in q} X_{o,d}^{Model} \right) \right]^2 + \sum_{p \in \mathcal{P}} \left[\log\left(X_{p,RoW}^{Data}\right) - \log\left(\sum_{o \in p} X_{o,RoW}^{Model} \right) \right]^2,$$

where $p, q \in \mathcal{P}$ indicate provinces and $o \in p$ denotes cities within province p; $X_{o,d}^{Data}$ and $X_{o,d}^{Model}$ are the trade flows from o to d in the data and model, respectively.

The problem in the inner loop is to choose $\{A_n^j\}$ such that equation (14) holds for all regions and sectors. The left-hand side and the total expenditure on the right-hand side of equation (14) can be directly calculated from the data. Therefore, the only unknowns in equation (14) are the trade shares π_{in}^j, which depend on wages (data), trade costs (estimated in the outer loop) and A_n^j. Intuitively, given trade costs and wages, the region specializing in sector k must be relatively more productive in that sector. Therefore, productivity A_n^j (subject to normalization) can be recovered by the following steps.[12]

We start with a series of initial guesses for A_n^j, and use them to solve for the prices and trade shares. We then check whether the demand for goods produced in each city-sector, i.e., the right-hand side of equation (14), equals those on the left-hand side (data). If not, we update the values for productivities by decreasing productivities (thus increasing prices) in region-sectors with excess demand, and increasing productivities (thus decreasing prices) in regions with insufficient demand. We repeat the process until we find the productivities that make the demand in the model equal to those observed in the data.

Preference Parameters The estimation of preference parameters requires data on prices and consumption shares. However, we do not have price data that are comparable across different regions, and the aggregate consumer expenditures by sector are only available at the province level. We solve the first issue using the model-implied prices. Once we have calibrated the productivities A_n^j, we can calculate the implied prices, P_n^j, from the model, and we use these implied prices in the estimation. Recognizing the second data limitation, we aggregate the city-level expenditure in the model to the province level and use these aggregated data for estimation.

Given the prices and consumption shares, we need to estimate five parameters with four constraints, i.e., $\alpha^j > 0$ and $\alpha^A + \alpha^M + \alpha^S = 1$. Following the treatment in Herrendorf et al. (2013), we transform these constrained parameters into unconstrained forms as follows:

$$\alpha^A = \frac{1}{1 + e^{b_1} + e^{b_2}}, \ \alpha^M = \frac{e^{b_1}}{1 + e^{b_1} + e^{b_2}}, \ \alpha^s = \frac{e^{b_2}}{1 + e^{b_1} + e^{b_2}},$$

---

[12] In Appendix C.2, Proposition C.1, we prove that, we can normalize productivity parameters, A_n^j, and calibrate an observationally equivalent equilibrium, as long we re-estimate the values of α^j and $\bar{c}^j$ along with A_n^j.

where $b_1, b_2 \in (-\infty, +\infty)$. Therefore, the problem is to search for the parameters b_1, b_2 and $\bar{c}^A, \bar{c}^S$ such that the model predicted province-sector level consumption share is closest to the data counterpart:

$$\min_{b_1, b_2, \bar{c}^A, \bar{c}^S} \sum_{n \in \mathcal{P}} \sum_{j \neq M} \left[S_n^{j,\, model} - S_n^{j,\, data} \right]^2. \tag{18}$$

Note that we drop the consumption share of manufacturing in equation (18) because it equals to one minus the shares of the other two sectors.

4.2.3 Parameters Estimated by Solving the Full Model

Once the previous calibration is completed, the remaining parameters, including separation costs, κ_{ni}, the utility weights, $\{\lambda_1, \lambda_2, \lambda_3\}$, region-sector specific amenities, B_{ni}^{kj}, and migration costs, $\mu_{od}^{\mathcal{H},j}$, can be estimated by solving the full model. We first impose some parametric restrictions on these parameters to lower their dimensionality. First, we assume that Members 1 and 2 receive the same utility weights in the household, while Member 3 can have a potentially different weight, i.e., $\lambda_1 = \lambda_2 \equiv \lambda, \lambda_3 = 1 - 2\lambda$. Second, the separation cost depends only on whether Members 1 and 2 work in the same city, and we set $\kappa_{ni} = 1 + (\kappa - 1) \times \mathbf{1}\,(n \neq i)$. Third, we restrict B_{ni}^{kj} to be separable based on the city-sector combinations of the two household members, i.e.,

$$B_{ni}^{kj} = B_n^k \times B_i^j.$$

Finally, similar to the trade costs in in equation (16), we parameterize the internal migration costs as follows

$$\log \mu_{od}^{\mathcal{H},j} = \sum_{i=1}^{4} \beta_i^{\mu} \times I_i + \sum_{i=1}^{3} \beta_{4+i}^{\mu} \times I_i \times Dist_{od} + \beta_8^{\mu} \times I_5, \tag{19}$$

The first seven terms in equation (19) are the same as in trade costs. We add one extra dummy variable, $I_5 \equiv \mathbf{1}(\mathcal{H} = \mathcal{R}, j \in \{M, S\})$, indicating rural-to-urban migration, capturing the extra costs for rural workers to work in the urban sector (Tombe and Zhu, 2019; Fan, 2019).

We estimate all these parameters using a nested procedure of three loops. In the inner loop, given all other parameter values, we search for a vector of city-sector-specific amenities $\{B_n^k\}$ such that the labor allocation across region-sector L_n^j must be the same as those observed in the data. The algorithm is similar to the way we recover productivities. In the middle loop, given the value of λ, we search for migration cost parameters $\beta_j^{\mu}, 1 \leq j \leq 8$ and a value of κ such that the model-predicted bilateral migration flows are closest to the data counterparts and the share of household moving together in the model equals the counterpart in the data (56%).[13]

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[13] We define the share of household moving together as the ratio of the number of households with Member 1 and 2 both migrate to that of households with at least one migrant.

Denoting the total number of workers from city o, *Hukou* sector $\mathcal{H}$ working in city d, industry j as $L_{od}^{\mathcal{H},j}$, we define the rural-to-urban migration flow between two cities as

$$L_{od}^{\mathcal{RU}} \equiv \sum_{j \in \{M,S\}} L_{od}^{\mathcal{R},j}$$

The objective function we minimize is

$$\sum_{o,d \in \mathcal{N}} \left(L_{od}^{\mathcal{RU},Model} - L_{od}^{\mathcal{RU},Data} \right)^2 + \sum_{o,d \in \mathcal{N}} \left[\left(L_{od}^{Model} - L_{od}^{\mathcal{RU},Model} \right) - \left(L_{od}^{Data} - L_{od}^{\mathcal{RU},Data} \right) \right]^2 . \tag{20}$$

Note that we have separated the rural-to-urban migration flows from the others. This helps us identify the rural-to-urban migration costs as mentioned above. Finally, in the outer loop, we search over the utility weight parameter λ such that the model-predicted share of total remittances in total migrants' income is the same as that in the data (14%).

4.3 Estimation Results

Preference Parameters Panel A of Table 3 shows the results. We find $\bar{c}^A$ to be negative and $\bar{c}^S$ to be slightly positive. This suggests that consumers have a subsistence requirement for agricultural goods and an endowment for service goods, consistent with Herrendorf et al. (2013) and Kongsamut et al. (2001).

Table 3: Calibrated Parameters by Solving the Model

Parameters	Values	Targets
Panel A: Preference parameters		
$(\alpha^A, \alpha^M, \alpha^S)$	(0.31, 0.42, 0.27)	Sectoral consumption shares by province
$\bar{c}^A$	-0.79	Sectoral consumption shares by province
$\bar{c}^S$	0.03	Sectoral consumption shares by province
Panel B: Separation cost and utility weights		
κ	11.63	Share of household moving togehter
$(\lambda_1, \lambda_2, \lambda_3)$	(0.40, 0.40, 0.20)	Share of remittances in migrants' income

Notes: we obtain sectoral consumption shares in each province from China Statistical Yearbook 2010. The share of households moving together and the share of remittances in migrants' income are calculated based on 2010 CMDS micro data. In the data, we define the share of households moving together as the ratio of the number of households with at least two migrants to that of households with at least one migrant.

Trade and Migration Costs Table 4 reports the calibrated parameters for trade costs and migration costs. The first column of Table 4 shows the results of trade costs. Shipping goods to a different city within the same province incurs an iceberg trade cost of 115 log points. Crossing the provincial border and the regional border further increase the trade costs by another 23 and 44 log points, respectively; while sharing a common provincial border reduces the costs by 6 points. Panel B of Table 4 reports the calibrated parameters for international trade costs, the manufacturing trade cost is lower than agriculture.[14]

The second column of Table 4 presents the calibrated results for migration costs. Migration costs increase in all distance measures, except for sharing a common provincial border. In particular, intra-provincial migration incurs extra costs of 344 log points; moving across provinces and across regions further increases the migration costs by 157 and 309 log points, respectively. However, migration to cities in another province but sharing the provincial border with the home city enjoys a 5 log points reduction in migration costs. Rural-to-urban migration incurs additional costs by 191 log points. Geographical distances also increase migration costs. If the origin and destination cities are within the same province, each additional 1,000 kilometers raise the costs by 640 log points. If the origin and destination cities are located in different provinces or regions, the marginal effects of distance become smaller, 309 and 188 log points, respectively. In short, the results indicate that migration costs are substantial and increase with both institutional and geographical barriers.[15]

Table 4: Calibration Result of Trade and Migration Costs

	Trade Costs	Migration Costs
Panel A: Domestic trade and migration costs calibration		
I_1(Different cities, same province)	1.15	3.44
I_2(Different provinces, same region)	1.38	5.01
I_3(Different regions)	1.59	6.53
I_4(Common provincial border)	-0.06	-0.05
I_5(Rural to urban)	-	1.91
$I_1 \times Dist$	-0.57	6.40
$I_2 \times Dist$	0.31	3.09
$I_3 \times Dist$	0.12	1.88
Panel B: International trade costs parameters		
Agriculture	0.37	-
Manufacturing	0.04	-

Notes: Panel A reports the calibration results of domestic trade costs and migration costs as in equations (16) and (19). $Dist_{od}$ is the great-circle distance between two cities o and d. Panel B reports the calibrated international trade costs parameters for agriculture and manufacturing goods, i.e., (t^A, t^M) in equation (17).

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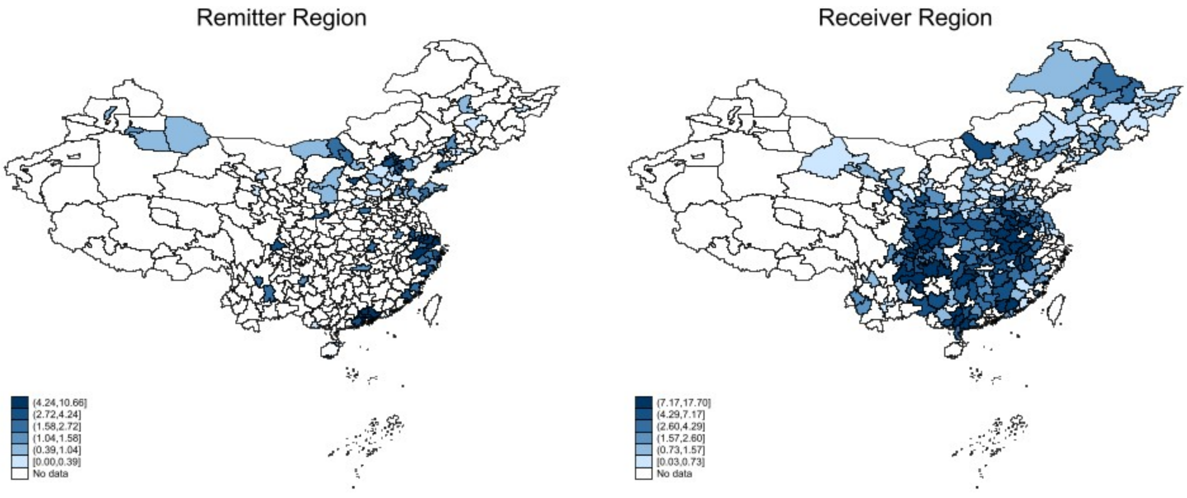
[14] Our estimates are qualitatively similar to those in Fan (2019) but smaller in magnitude. We also use the estimates in Fan (2019) as a robustness check in Online Appendix D.2, and the main counterfactual findings are robust to these alternative trade costs.

[15] The magnitude of the migration costs we estimate is larger than those in Fan (2019), because according to our definition of the household utility function (equation 10), migration costs are scaled by each member's utility weight, λ_1 and λ_2. In our calibration, both parameters equal 0.4, significantly smaller than one.

Separation Cost and Utility Weights The calibrated separation cost and utility weights are reported in Panel B of Table 3. To match the joint migration probability of 56% in the data, we find a large iceberg separation cost of 11.63. This suggests that, holding everything else constant, the utility of households with two members working in different cities is 91% lower than households with two members working in the same location (1/11.63 - 1 = - 0.91).

As is reported in the same table, we find the utility weights of the three household members to be 0.40, 0.40 and 0.20, respectively. The utility weight of the third member is around half of that of Members 1 and 2. Though not directly comparable, these weights are roughly consistent with the common practice of assuming that a child needs around 1/2 of the consumption expenditure of an adult to maintain the same standard of living when comparing the income of households of different sizes. (see OECD equivalence scale or "Oxford scale" in OECD (1982) and Atkinson et al. (1995))

We further present the distribution of the model-implied remittances across regions in Figure 1. The outcome variable in Figure 1 is the remittances' share of GDP, and we use a deeper color to indicate a larger share. The majority of the cities, 201 out of 284, receive net remittances. Specifically, Sichuan and Henan provinces have the largest number of remittance-receiving cities. Ziyang and Bazhong in Sichuan are the two cities with the largest share of remittances in GDP. The remitter cities are concentrated on the east coast. Shenzhen, Zhuhai and Zhongshan from Guangdong province are the top three cities with the highest share of net remittance outflow in GDP. This pattern is consistent with the fact that cities in Guangdong attract a large number of migrants in China.



(a) Remitter Region

(b) Receiver Region

Figure 1: Distribution of Remittances

Notes: Figure 1(a) displays net remittance outflows as shares of GDP, for remitter regions only; Figure 1(b) displays net remittance inflows as shares of GDP, for receiver regions only . "No Data" means that the prefecture is either not in our sample or not a remitter region in panel (a) (not a receiver region in panel (b)).

4.4 Model Fit

In this section, we examine the goodness of fit of our calibrated model by comparing data and model moments. We parameterized and estimated consumers' Stone-Geary preferences. In Figure 2, we compare the predicted and actual agricultural and services consumption shares in each Chinese province in 2010. All the points are scattered around the 45-degree line. The correlation between the model and the data is 0.87.

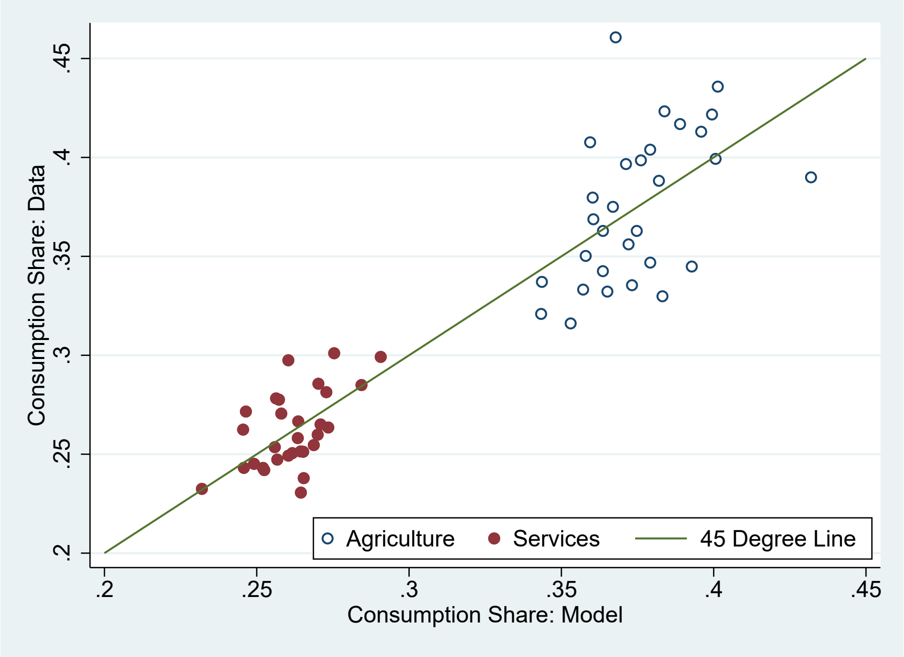
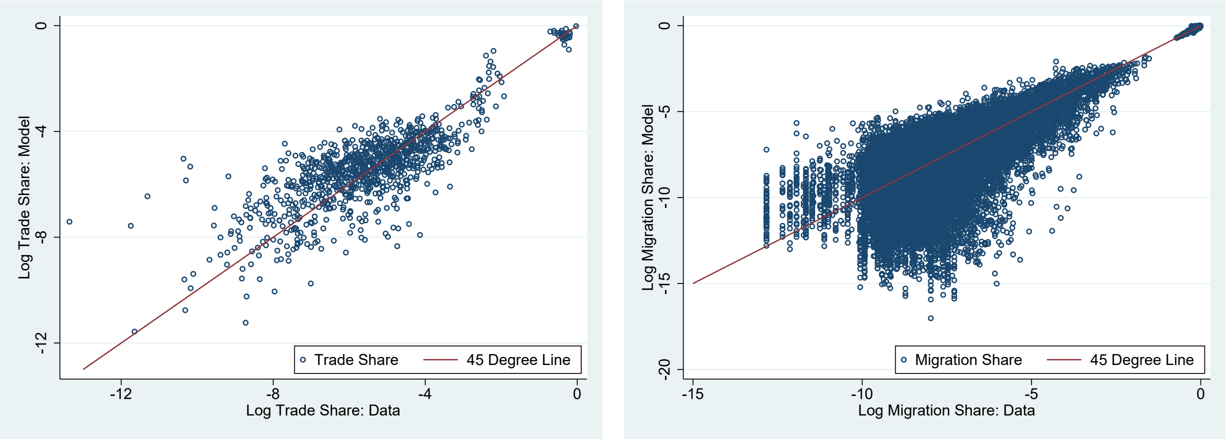


Figure 2: Fit of Consumption Shares

Notes: The vertical axis indicates the consumption shares in the data, and the horizontal axis displays the consumption shares fitted by the model. Each dot or circle represents the consumption share of a province for agriculture or services. The correlation between the model and the data is 0.87.

We now examine how our model fits the bilateral trade and migration shares. We parameterized the trade and migration costs according to equations (16) and (19), and estimate the parameters in these specifications by minimizing the distance of trade and migration flows between the model and data. In Panel (a) of Figure 3, we plot the log of the predicted trade shares (bilateral trade flows divided by total absorption in the destination province) against those in the data. Each point represents a pair of provinces instead of cities since we only have bilateral trade flows at the province level. The predicted trade shares are close to those in the data, and the correlation between the two is 0.81. Panel (b) of Figure 3 contrasts the predicted migration shares, as defined in equation (13). The migration shares in the model and data are also highly correlated, with a correlation coefficient of 0.70.

In Figure 4, we examine the variation of the share of household moving together and the share of remittances in migrants' income across households with *Hukou* in different provinces. In our calibration, we choose parameters to match the nationwide share of moving together



(a) Trade Share (b) Migration Share

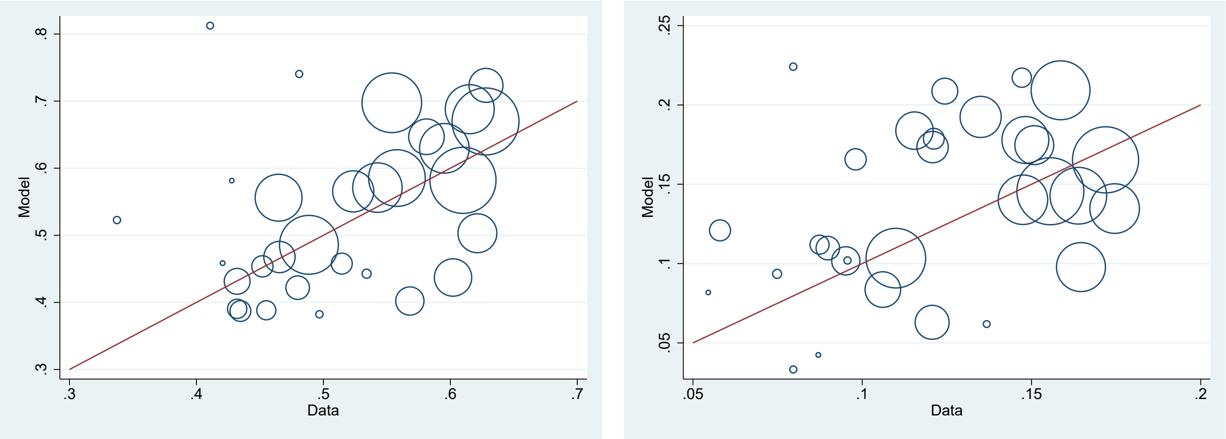
Figure 3: Model Fitting: Trade Share and Migration Share

Notes: Panel (a) plots the log of provincial bilateral trade shares in the model and data, where trade shares are defined as trade flows divided by total absorption in the destination province. Panel (b) plots the log of city-level bilateral migration shares in the model and data, where migration shares are defined in equation (13). The solid line through the dots is the 45-degree line. The correlation between the model and data is 0.81 for trade shares and 0.70 for migration shares.

and the share of remittances in migrants' income but do not explicitly target these values by the home city of households. In our data, we do not know the home cities of migrants, but we know their home provinces. We therefore calculate these shares by home provinces in the model and data and plot the former against the latter in the two panels of Figure 4. Each circle in the two panels represents a province, and the area of the circle is proportional to the total number of migrants from the province in the 2010 population census. In Panel (a), we find that our model provides reasonable predictions for the share of households moving together by home provinces, with a positive correlation of 0.59. As illustrated by Panel (b), there is also a positive correlation between the share of remittances in migrants' income in the model and that in the data, with a correlation coefficient of 0.34. In Panel (b) of Online Appendix Figure C.2, we show that the share of remittances in migrants' income in the model is strongly affected by the home provinces' per capita income, which is consistent with Corollary 1. Panel (a) of Figure C.2 shows that this relationship, though weaker, also holds in the data. This mechanism helps to generate the positive correlation in Panel (b) of Figure 4.

5 Counterfactual Analysis

We now use the calibrated model as a laboratory to conduct counterfactual experiments and to quantify the impact of remittances on sectoral shares and welfare.



(a) Share of Household Moving Together (b) Share of Remittance in Migrants' Income

Figure 4: Household Moving Together and Remittance Behavior, by Origin Province

Notes: Panel (a) plots the model-implied share of households moving together against the data counterpart (CMDS 2010); Panel (b) plots the model-implied share of remittance in total migrants' income against the data counterpart (CMDS 2010). We calculate the shares based on the home province of the migrants. Each bubble represents a province, and the area of the bubble is proportional to the total number of migrants from this province in the 2010 census data. The solid line through the circles is the 45-degree line. The correlation between the model and data is 0.59 for the share of household moving together and 0.34 for the share of remittance in migrants' income. The definition of moving together can be found in Footnote 13.

5.1 The Impact of Banning Migrants' Remittances

In the first counterfactual experiment, we ask what would happen if the cost of sending remittances were prohibitively high such that no migrants send remittances. This counterfactual helps us understand the role of remittances in our model. Moreover, the last two decades saw rapid development of online banking and payment systems, which reduced the costs of sending remittances significantly. Therefore, the counterfactual also helps us to think about the potential effects of such a decline in remittance costs.

Specifically, we assume that migrants cannot send remittances to support family members left behind, while transfers between family members are still allowed if they do not migrate or if they migrate together.[16] In this case, the optimal transfers between household members staying in their hometown will be different from those when the migrants' remittances are allowed. (we derive the new optimal transfer formulas in Appendix B.4) We then compare the results under no migrants' remittances to our benchmark case.

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[16] For example, if Members 1 and 2 migrate together, they cannot send remittances to Member 3, but they can transfer income between themselves. If Member 2 migrates, but Member 1 stays, Member 2 cannot remit income back home, but Member 1 can transfer income to Member 3. Finally, if all members stay, we do not impose restrictions on within-family transfers other than $T_1 + T_2 \geq 0$, which is the same restriction as in our baseline model.

5.1.1 Sectoral Employment Shares and Migration

Table 5 reports the change in sectoral employment shares when banning remittances. The key finding is that removing remittances drives employment from services and manufacturing to agriculture. Overall, banning remittances raises the share of employment in agriculture by 0.9 p.p and reduces the share in manufacturing and services by 0.4 p.p and 0.5 p.p, respectively. This impact is not negligible given that the decline in the share of nationwide agriculture employment is 8.1 p.p from 2005 to 2010. We also find a larger quantitative impact on structural change in the receiver regions than in the remitter regions.

Banning remittances also hinders migration. Aggregate migration decreases by 2.9% if remittances are not allowed. A migrant can simultaneously improve his/her own utility through migration and other family members' utility through remittance, both ultimately leading to higher household utility. Banning remittance reduces the household's gain from migration, thus reducing total migration. Moreover, given that migrants are more concentrated in the manufacturing sector,[17] this finding may also explain why the manufacturing employment share declines more than services in the remitter region (as in Panel C of Table 5). We later provide a formal model-based decomposition to quantify how much the change in migration incentives after banning remittances affects structural change.

Figure 5 plots the changes in agriculture (or services) employment shares against the shares of remittances in GDP in the baseline equilibrium to examine the heterogeneous impacts across cities. The impact of removing remittances on agricultural employment shares is positively correlated with the share of net remittances in GDP in the baseline equilibrium, while its impact on services employment shares is negatively correlated with the share of net remittances. For instance, the impact of removing remittances on structural change is large in top receiving cities. Ziyang, the city with the highest net remittance share, see a 1.7 p.p reduction in services employment and a 2.0 p.p increase in agriculture employment after remittances are banned.

Decomposition of Mechanisms In the absence of remittances, the recipients lose extra income, and the remitters have to spend all their wages locally. Changes in consumers' behavior lead to adjustments in the supply side, thus inducing labor reallocation across sectors. Four possible mechanisms contribute to the changes in sectoral employment share. First, in a model with constant consumption shares across sectors, i.e., Cobb-Douglas preferences, remittances will increase the local production share of non-tradables because the increase in demand for tradables will partially fall onto output in the other regions. We call this effect *unequal demand change*. The second mechanism is the *price effect*. The unequal demand effect induces an increase in the relative prices of non-tradables and therefore leads to an increase in the consumption shares of non-tradables when tradables and non-tradables are complements. Third,

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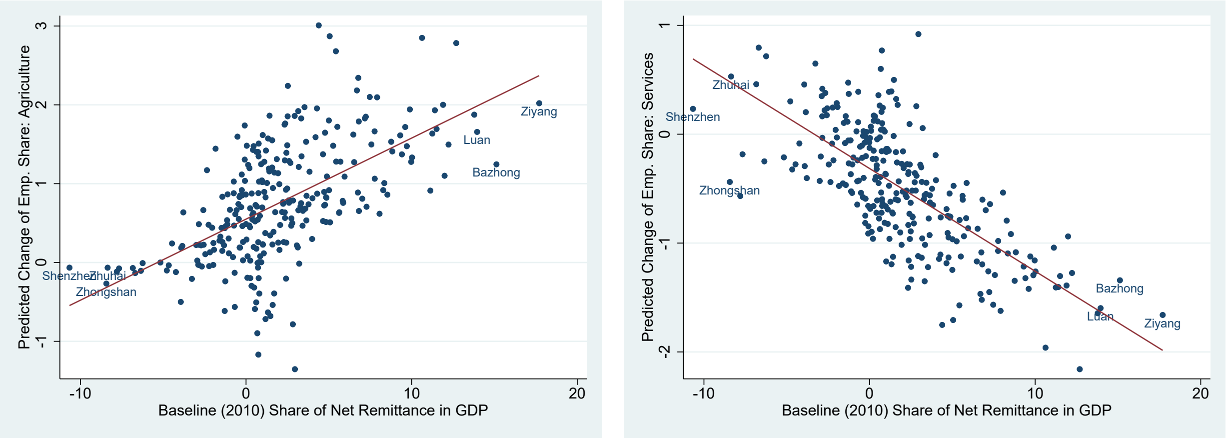
[17] From the 2010 Census data, we know that around 57% of migrants work in the manufacturing sector.

Table 5: Change in Sectoral Employment Shares: Banning Remittances

	Baseline: With Remittances	Counterfactual: Banning Remittances	Change
A. Overall			
Agriculture	42.1	43.0	0.9
Manufacturing	27.3	26.9	-0.4
Services	30.6	30.1	-0.5
B. Receiver Region			
Agriculture	58.1	59.1	1.0
Manufacturing	18.6	18.3	-0.3
Services	23.3	22.6	-0.7
C. Remitter Region			
Agriculture	22.9	23.3	0.4
Manufacturing	37.7	37.4	-0.3
Services	39.4	39.4	-0.0

Notes: Columns 2 and 3 report the employment share (%) in the benchmark with remittances and in the counterfactual banning remittances, respectively. Column 4 is the corresponding percentage point change. The change of three sectors may not sum to 0 due to rounding.



(a) Agriculture

(b) Services

Figure 5: Heterogeneous Impacts of Banning Remittances

Notes: Figure 5(a) plots the changes of agriculture's employment shares against the shares of net remittances in GDP. Figure 5(b) plots the changes of services employment shares against the shares of net remittances in GDP. Each dot represents a city. The solid line is the line of best linear fit in each plot. Negative values on the horizontal axis indicate net outflows of remittances, while positive values mean net inflows. The correlations between the share of remittances in GDP and the changes in agriculture and services employment shares are 0.58 and -0.71, respectively.

our non-homothetic preferences (Stone-Geary) generate a direct *income effect*: as recipients become richer due to remittances, they consume more services and fewer agricultural goods. Finally, given our previous analysis, migration declines after banning remittances, which can potentially increase agriculture shares and reduce manufacturing and services shares. We refer to the last mechanism as the *migration effect*.

Given that the Stone-Geary preference setup (baseline) captures all mechanisms, we decompose the roles of the first three mechanisms by changing the Stone-Geary preference (SG) to constant elasticity of substitution (CES) and Cobb-Douglas (CD) preferences. In particular, the income effect can be identified by comparing the results of banning remittances under the SG preference to those under the CES preference. Comparing the results under the CES preference to those under CD, we obtain the price effect. Finally, the effect of banning remittances under the CD preference will be informative about the strength of the unequal demand change mechanism.

To isolate the migration effect, we first solve the equilibrium under the CD preferences with remittances (initial equilibrium, denoted by CD^0). We next solve a "fixed-migration no-remittance equilibrium" (denoted by $\overline{CD^1}$) by fixing the household migration patterns at the initial equilibrium levels, banning remittances and then allowing workers to change their industries locally.[18] The difference between the fixed-migration no-remittance equilibrium ($\overline{CD^1}$) and the equilibrium under CD preferences without remittances (CD^1) reveals the migration effects, because the migration patterns in the former are fixed at the initial equilibrium, while migration in the latter responds to the removal of remittances. We provide a graphical illustration of the decomposition in Online Appendix Figure C.1.

The decomposition results are displayed in Figure 6. Overall, the unequal demand change effect contributes the most to the changes in sectoral shares after banning remittances. For instance, at the national level, the unequal demand change mechanism contributes to 50% of the increase in agriculture's employment shares, and 36% and 61% of the decline in manufacturing's and services' employment shares, respectively. This mechanism is even more important in explaining the results for the receiver cities, which experience a large decline in the employment share of services due to the removal of remittances. The income and migration effects are also quantitatively important, each explaining around half of the changes in sectoral shares that are not explained by the unequal demand change mechanism. We find that the price effect is negligible in explaining the impact of banning remittance on sectoral shares.

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[18] By "fixing household migration patterns", we fix the number of households with a certain combination of home city o, *Hukou* type $\mathcal{H}$, Member 1 location n and Member 2 location i, and whether any member has migrated (denoted by an indicator variable $\mathcal{M}$). For households within the cell $(o, \mathcal{H}, n, i, \mathcal{M})$, we allow Members 1 and 2 to re-optimize and choose their sectors of employment. Note that, when re-optimizing, we impose the same restriction as in our baseline model that non-migrant rural workers ($\mathcal{H} = \mathcal{R}, \mathcal{M} = 0$) have to work in agriculture and within-city migrant workers ($\mathcal{H} = \mathcal{R}, \mathcal{M} = 1, n = o$ or $i = o$) work in manufacturing/services.

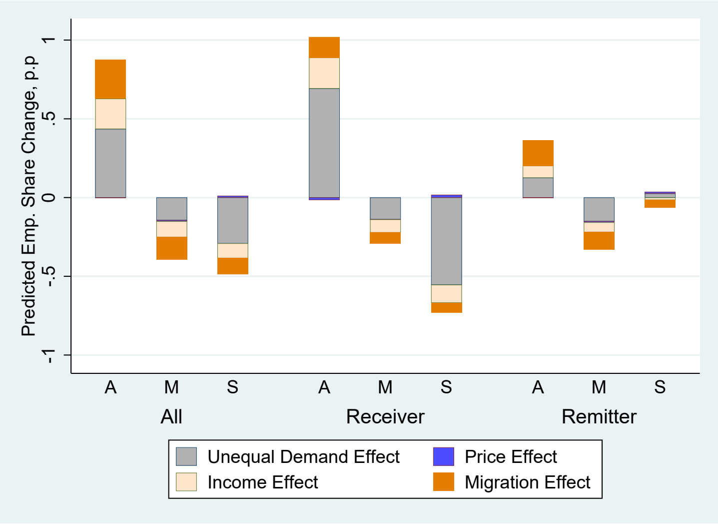

Figure 6: Decomposition Results

Notes: A, M, and S denote agriculture, manufacturing and services, respectively. The vertical axis indicates the percentage point changes in employment shares. The length of bars with different colors, as indicated in the legend, represents the magnitude of the corresponding mechanism. The income effect is captured by subtracting the impacts of banning remittances under CES preferences ($\triangle CES$) from the baseline results under SG preferences ($\triangle SG$). The price effect is calculated by subtracting the impacts of banning remittances under CD preferences ($\triangle CD$) from the results under CES preferences ($\triangle CES$). The change from the "fixed-migration no-remittance equilibrium" ($\overline{CD^1}$) to the equilibrium under CD preferences with remittance (CD^0) reveals the unequal demand change effect. The difference between the equilibrium under CD preferences banning remittance (CD^1) and $\overline{CD^1}$ captures the migration effect. See Appendix C.3 for details of the decomposition.

5.1.2 Welfare and Inequality

We now analyze the impacts of banning remittances on welfare and regional inequality. We adopt two measures for welfare. First, we calculate the percentage change in real income per worker (in destination cities) in the no-remittance counterfactual relative to the baseline. With this measure, we can further decompose the change in real income into the change in prices and the change in nominal income. The second measure is the percentage change of household expected utility in each home city, taking into account the migration costs.[19]

Panel A in Table 6 reports the results. As for the real income per worker, the whole economy would suffer a loss of -0.8% from banning remittances. The remitter regions experience a gain of 3.9%, while the receiver regions suffer a loss of 5.0%. We further decompose the change of real income into changes in prices and nominal income. The receiver region suffers mainly from the lowered nominal income (-5.4%), even though the loss of remittances resulted in lower prices (-0.3%). Similarly, the gain in the remitter region is dominated by the increase in nominal income,[20] despite the fact that migrants have to spend all their income locally, which

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[19] In Online Appendix B.5, we derive the expression for the expected household utility. Due to the existence of migration frictions, the utility is specific to households' home cities and *Hukou* registration types. We take the average of the expected utility using the number of households as weights.

[20] The change in nominal income is mainly driven by banning remittances. In the baseline model with re-

simultaneously causes the prices to rise.

Welfare, measured in household ex-ante expected utility and averaged across all home cities and *Hukou* types using the number of households as weights, declines by 0.6% nationwide, similar to the decline in aggregate real income. Different from the destination-city-based income measure, which increases in the remitter cities, households from the richest cities may experience declines in expected utility. This is because, both in the model and in the data, workers from the richest cities may still migrate to other cities, and their households are worse off when they face more constraints (banning remittances). In addition, we see that the decline in welfare is larger for households in the receiver cities (-3.6%) than that for households in the remitter cities (-0.2%), likely because households in receiver cities depend much more on remittances as an income source.

In Panel B of Table 6, we further analyze the impact of banning remittances on regional inequality by calculating the variance of log real income and household expected utility across households from different home cities. Banning remittances causes the variance of log real income to increase from 0.10 to 0.18 (rounded to two decimal places), a 77.8% increase. The increase in inequality is much smaller if we measure welfare using the household expected utility. The variance of log household utility rises from 1.81 to 1.86, a 2.8% increase. The results based on household utility are different from those based on real income because household utility takes into account the connection between household members. For example, when a migrant is prohibited from sending remittances home, it increases the per capita income in the destination city and lowers that in the home city. However, the migrant enjoys more consumption, which compensates for the loss of consumption by the left-behind members because the household utility is a weighted geometric mean of all members' consumption. Therefore, the increase in inequality measured by the household utility will be smaller than when measured by destination cities' real income per capita.

5.2 The Impact of Changes in Productivities and Migration Costs

So far, we have studied the impact of remittances on structural change and welfare. China has experienced structural reforms and dramatic increases in domestic migration since the 1990s. In this section, we analyze two key drivers of these changes through the lens of our model: improvements in sectoral productivities and reductions in domestic migration costs.[21] We then ask how these changes affect aggregate welfare and sectoral shares, and compare the implications of our model with conventional single-member household models.

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mittances, the share of remittance received in GDP is 3.4% for receiver cities; for remitter cities, the share of remittance sending out in GDP is 3.5%.

[21] We focus on the productivity change and migration cost reduction between 2000 and 2010 since these two forces explain around 90% of the structural change and real GDP growth in China during the decade (Hao et al., 2020).

Table 6: The Impacts of Banning Remittance on Welfare and Inequality

	(1) All Cities	(2) Receiver Cities	(3) Remitter Cities
Panel A: Population-weighted Aggregate Variables			
△% Price	-0.01	-0.3	0.3
△% Nominal Income	-0.9	-5.4	4.3
△% Real Income	-0.8	-5.0	3.9
△% Household Welfare	-0.6	-3.6	-0.2
Panel B: Income/Welfare Inequality			
Var(Log Real Income) : Benchmark	0.10	0.10	0.07
Var(Log Real Income) : Ban Remittance	0.18	0.19	0.11
△% Var(Log Real Income)	77.8	91.7	67.2
Var(Log Household Welfare): Benchmark	1.81	0.80	1.92
Var(Log Household Welfare): Ban Remittance	1.86	0.83	1.95
△% Var(Log Household Welfare)	2.8	3.5	1.2

Notes: Panel A reports the impacts of banning remittance on the population-weighted aggregate variables. Panel B reports the inequality measured by the variance of log real income per capita and household welfare under the benchmark and the banning remittance counterfactual and the change in inequality induced by banning remittance. △% denotes the percentage change.

In particular, we start from the calibrated Chinese economy in 2010 and estimate the city-sector-specific productivities and migration costs in 2000. We change the productivities A_n^j such that we can match the real GDP per worker in 2000, following Tombe and Zhu (2019) and Hao et al. (2020).[22] The estimated changes in sectoral productivity reflect the changes in real GDP per worker in the data. In table 7, we present statistics related to real GDP per worker. From 2000 to 2010, real GDP per worker, on average, increased by 138% and 135% in agriculture and services sectors in all our sample cities. The increase in manufacturing GDP per worker is smaller (82%) compared to the other two sectors. We also find that receiver cities experienced faster growth in agriculture and services but slower growth in manufacturing, compared to the remitter cities. At the city level, we observe strong convergence of real GDP per worker. The variance of log real GDP per worker shrank by 57% over the decade.

For migration costs, we parameterize the change in migration costs from 2000 to 2010 as

$$\log \hat{\mu}_{od}^{\mathcal{H},j} = -\alpha_0^{\mu} \times \mathbf{1}(o \neq d) - \alpha_1^{\mu} \times \mathbf{1}(\mathcal{H} = \mathcal{R}, j \in \{M, S\}).$$

In this expression, α_0^{μ} controls the reduction in cross-city migration costs and α_1^{μ} controls the

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[22] One challenge in constructing real GDP is the lack of city-sector-specific GDP deflators. Following Hao et al. (2020) and Tombe and Zhu (2019), we use the provincial-level Consumer Price Index (CPI) from China Statistic Yearbook as the deflators. Then we calculate the change in real GDP per worker from 2000 to 2010. To reduce the impact of outliers (small cities with exceptionally high growth rates), we winsorize the city-level Real GDP per worker growth at the top 5% for each sector.

Table 7: Observed change in real GDP per worker, 2000 - 2010

	(1) All Cities	(2) Receiver Cities	(3) Remitter Cities
$\triangle\%$: Total Real GDP per worker	136.2	149.1	106.8
$\triangle\%$: Real GDP per worker: Agriculture	138.2	156.3	104.4
$\triangle\%$: Real GDP per worker: Manufacturing	82.2	59.3	95.1
$\triangle\%$: Real GDP per worker: Services	135.0	149.6	122.5
Var(Log Total Real GDP per worker):2000	0.14	0.10	0.12
Var(Log Total Real GDP per worker):2010	0.06	0.05	0.03
$\triangle\%$: Var(Log Total Real GDP per worker)	-57.0	-48.9	-71.8

Notes: The first four rows report the observed percentage change in total, agriculture, manufacturing and services real GDP per worker, respectively. The last three rows display the variance of log real GDP per worker in 2000 and 2010, and the percentage change in the variance from 2000 to 2010. $\triangle\%$ denotes the percentage change.

reduction in rural-to-urban migration costs. We normalize the value of $\mu_{od}^{\mathcal{H},j}$ for non-migrants to one in both years. From 2000 to 2010, total cross-city and total rural-to-urban migration increased by 299% and 121%, respectively.[23] We start from our baseline economy in 2010 and search for values of α_0^{μ} and α_1^{μ} so that we exactly match the total cross-city and total rural-to-urban migration in 2000. We find $\alpha_0^{\mu} = 1.61$ and $\alpha_1^{\mu} = 1.81$, indicating large reductions in cross-city and rural-to-urban migration costs, respectively.

Columns 1-4 of Table 8 report the effects of productivity changes and migration cost reduction on various outcomes in our household model with remittances. As we have estimated the productivities and migration costs in 2000 (denoted by $A_n^{j,2000}$ and $\mu_{od}^{j,2000}$), we use these values to calculate the equilibrium in 2000, and display the related outcomes in Column 1. We use this as the benchmark and then change migration costs and productivities to the levels in 2010 in Columns 2 and 3, respectively. Finally, Column 4 presents the calibrated economy in 2010, allowing both migration costs and productivities to change from the 2000 levels.

Panel A of Table 8 summarizes remittances and migration behavior in different scenarios. Comparing the first two columns, we find that the reduction in migration costs alone increases migration by 99%, and the share of households with members moving together increases from 34% to 54%. Because of more joint migration, migrants send, on average, a smaller share of their income as remittances (16.3% instead of 23.5%).[24] However, since more people migrate under lower migration costs, the share of total remittances in GDP increases from 1.1% to 2.1%. Comparing Columns 1 and 3, productivity changes during this period have a very small effect on total migration, only increasing it by 3.2%. Moreover, because of the convergence

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[23] Note that the rural-to-urban migration includes the intra-city and the cross-city rural-to-urban migration and that the latter is also part of the cross-city migration.

[24] The third member has a utility weight of only 0.2, much smaller than the combination of Members 1 and 3 (0.6). Therefore, migrants send a smaller share of their income back home under joint migration.

Table 8: The Impacts of Changing Productivities and Migration Costs

	Household Model				Single-Person Model			
	(1) Calibrated 2000	(2) $\mu_{od}^{j,2000} \to \mu_{od}^{j,2010}$	(3) $A_n^{j,2000} \to A_n^{j,2010}$	(4) Calibrated 2010	(5) Calibrated 2000	(6) $\mu_{od}^{j,2000} \to \mu_{od}^{j,2010}$	(7) $A_n^{j,2000} \to A_n^{j,2010}$	(8) Calibrated 2010
Panel A. Remittances and Migration								
Share of Remittances in GDP (p.p)	1.1	2.1	0.9	1.7				
Share of Remittances in Migrants' Income (p.p)	23.5	16.3	21.9	14.2				
Share of Households Moving Together (p.p)	34.4	54.3	35.6	56.0				
△% Total Migration	-	98.9	3.2	107.3	-	99.6	5.7	111.8
Panel B. Structural Change (relative to 2000)								
△ Agriculture Emp. Share (p.p)	-	-14.0	-1.0	-16.2	-	-13.0	-2.0	-16.4
△ Manufacturing Emp. Share (p.p)	-	7.0	0.5	8.3	-	6.5	1.1	8.4
△ Service Emp. Share (p.p)	-	6.9	0.5	8.0	-	6.5	0.9	8.0
Panel C. Welfare and Inequality (relative to 2000)								
△% Average Real Income	-	11.7	109.9	135.9	-	11.9	109.5	134.8
△% Average Household Welfare	-	22.2	162.9	221.5	-	22.2	150.8	211.1
Var(Log Real Income)	0.21	0.16	0.20	0.10	0.32	0.26	0.28	0.18
△% Var(Log Real Income)	-	-25.1	-6.4	-50.2	-	-18.0	-10.4	-44.3
Var(Log Household Welfare)	2.25	1.85	2.23	1.81	1.52	1.28	1.49	1.25
△% Var(Log Household Welfare)	-	-17.5	-0.8	-19.5	-	-15.7	-2.4	-18.0

Notes: This table reports the impacts of changing productivities and migration costs in the benchmark household model (Columns 1-4) and the single-person model (Columns 5-8). For the household model: Column 1 summarizes the related outcomes in the calibrated economy in 2000; Columns 2 and 3 present the impacts of changing migration costs and productivities to the levels of 2010, respectively; Column 4 compares the calibrated 2010 economy to 2000, allowing both migration costs and productivities to change from the 2000 levels. Columns 5-8 present the corresponding results in the single-person model. Panel A summarizes migrants' remittances and migration behavior. Panel B reports changes in sectoral employment shares. Panel C reports the percentage change of the level and inequality of welfare, measured by real income per worker and ex-ante household welfare. △% denotes percentage changes, all relative to the 2000 calibrated economy.

in productivities across cities (as demonstrated in Table 7), migrants send on average a smaller share of income as remittances and the nationwide share of remittances in GDP declines from 1.1% to 0.9%. Finally, contrasting Columns 1 and 4 reveals the combined effect of changes in migration costs and productivities.

We present counterfactual changes in sectoral employment shares in Panel B. Changes in both migration costs and productivities contribute to the structural change, i.e., a lower employment share in agriculture and higher shares in non-agricultural sectors. However, the contribution of migration cost reduction is overall much larger than that of productivity changes. This finding is consistent with other studies using different models and calibration procedures, such as Hao et al. (2020).

In Panel C, we summarize how changes in migration costs and productivities affect welfare and inequality. Since we need large increases in productivities to match the increases in real GDP per worker (Table 7), it is not surprising that productivity changes drive large increases in the average *level* of real income (+109.9%) and household welfare (+162.9%). Reduction in migration costs also improves real income and welfare, but to a lesser extent (+11.7% and +22.2%, respectively, when changing migration costs alone). Both changes cause convergence in real income and welfare across cities, with the reduction in migration costs (Column 2) having a larger impact on inequality than changes in sectoral productivities (Column 3).[25]

Comparison to a Single-Person Model Our model emphasizes household migration and remittance decisions. How will results differ if we use a conventional single-person migration model as in Redding (2016) and Tombe and Zhu (2019)? We now calibrate a single-person migration model and compare the counterfactual results to our household model. In the single-person model, each worker makes his/her location-sector choice independently to maximize his/her own utility and has no motives to send remittances back to the home city. We do not change parameters that are calibrated independently (Table 2). For sectoral productivities in 2010, trade costs and preference parameters, our previous estimation strategy is to invert part of the model and is not affected by changing the model setup to single-person migration. Therefore, we keep the previously estimated values. Finally, we re-estimate the migration cost parameters in equation (19) and city-sector amenities B_n^j by matching migration flows and sectoral employment in each city. Note that the separation cost κ and utility weight parameter λ are irrelevant in the single-person model.

We then perform the same counterfactual analysis as we do with the household model in Columns 1-4 of Table 8, and present the corresponding results in the single-person model in Columns 5-8. For example, in Column 6, we re-estimate the pair of migration cost changes $\alpha_0^\mu, \alpha_1^\mu$ to match the total cross-city and rural-to-urban migration in 2000 in the single-person model. Because total migration in 2010 is not exactly the same in the household and single-person models (we do not target the total migration when calibrating the 2010 economy), the predicted changes in the counterfactuals in Columns 2 and 6 do not equal. However, they are very close to each other and make it possible for us to compare other outcomes in response to migration cost reduction in these two models.

Regarding the impact of changing migration costs and productivities on structural change (Panel B), we find the single-person model under-predicts structural change when we reduce the migration costs from the 2000 to 2010 levels (Column 2 v.s. Column 6), while it over-predicts structural change when we change the sectoral productivities (Column 3 v.s. Column 7). One potential explanation for this discrepancy is that remittances respond differently to the change in migration costs and productivities in the household model. When migration costs are reduced, more people migrate, and the share of remittances in total GDP increases from 1.1% to 2.1%. As we have seen from the counterfactual of banning remittances, more remittances tend to speed up structural change by reducing employment in agriculture and raising employment in manufacturing and services. In contrast, productivity changes reduce the share of remittances

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[25] Compared to the literature (Hao et al., 2020; Tombe and Zhu, 2019), we find a larger impact of migration costs on inequality in China, likely because our analysis is at the city level instead of province level. For example, our results are in line with Fan (2019), which also uses cities as the unit of analysis. In addition, we introduce remittance, which further reduces inequality in response to a reduction in migration costs.

in total GDP because the productivities grow on average faster in the receiver cities during this period, becoming a force that slows down structural change. However, the endogenous changes in remittances are shut down in the single-person model. Therefore, compared to the single-person model, our household model amplifies (dampens) the structural change in response to structural change in response to migration cost reduction (productivity growth). Combining the two shocks, the two models have very similar predictions on the changes in sectoral employment shares (Column 4 v.s. Column 8).

In Panel C, we further compare the two models' implications on income and welfare inequality. We have shown that remittances can mitigate cross-region inequality in Section 5.1.2. In our household model, remittance shares in total GDP increase with migration cost reduction and decrease with productivity changes. Therefore, compared to the single-person model, the household model predicts a larger reduction in inequality in response to migration cost changes and a smaller reduction in inequality in response to productivity changes. For example, when we lower the migration costs from 2000 to 2010 levels, the household model predicts a 25% reduction in the variance of log real income across regions, while the single-person model predicts an 18% reduction. The discrepancy in terms of changes in welfare inequality is smaller. Similar to income inequality, we find the single-person model under-predicts the reduction in welfare inequality under migration cost changes and over-predicts its reduction under productivity changes.

5.3 Sensitivity Analysis

We examine the sensitivity of our main results along two additional dimensions. First, an alternative choice for non-homothetic preference is the Price Independent Generalized Linearity (PIGL) specification. We now replace the Stone-Geary preference with PIGL. Specifically, following Boppart (2014), we assume agricultural goods are necessities, services goods are luxuries and manufacturing goods are neutrals. We express the household integral indirect utility function as the weighted sum of each member's indirect utility. Then, we can obtain closed-form expressions of optimal remittances by solving the household optimization problem. Online Appendix D.1 describes the details of derivation, calibration and results under this setup. Though smaller in magnitude, We find banning remittances hinders structural change and increases inequality as in our baseline model.

We also evaluate the sensitivity of our baseline results to alternative trade cost parameters. We borrow the coefficients of trade cost estimation from Fan (2019), and recalibrate the model to conduct the same experiments of banning remittances. Online Appendix D.2 discusses the implementation details and counterfactual results. We find our main results are robust to these alternative trade costs.

6 Conclusion

The cross-border or cross-region movement of migrants is accompanied by remittances to support those family members left behind in the home region. This paper studies the joint impact of internal migration and remittances on the development of various regions in China. We develop a spatial equilibrium model with household decisions on migration and remittances and calibrate the model to the Chinese economy in 2010. Our main findings are that remittances increase migration and welfare, reduce regional income inequality and facilitate the reallocation of labor from agriculture to manufacturing and services. Moreover, compared to a conventional single-person model without remittance motives, our household model suggests a larger reduction in regional inequality and stronger reallocation of employment from agricultural to manufacturing and services in response to the decline in migration costs over the period of 2000 to 2010. Therefore, it is important to incorporate household migration and remittance decisions to understand the impact of productivity and migration frictions on economic development.

The framework we develop here can also be used to evaluate international remittances, because large remittances are usually associated with household endogenous choices of migration at the same time. For example, the common labor market in the European Union causes large inflows and outflows of labor and remittances, which may have strong implications for welfare and structural change in different European countries (Caliendo et al., 2017; Blouri and Ehrlich, 2020).

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Online Appendix - Not for Publication

A Additional Empirical Results

A.1 Data Description and Additional Results using CMDS

Since 2009, the National Health Commission of China has conducted the China Migrants Dynamic Survey (CMDS). This survey collects data on migrants aged 16 to 60 through a series of questionnaire-based interviews on a yearly basis. We focus on the wave of 2010, which covers 100 cities and 128,000 observations. Specifically, CMDS provides information on migrants' origin province, the destination city, the amount of remittances sent home, the number and employment status of family members moving together, and the total household income in the destination city. Moreover, CMDS provides the sample weight for each observation so that we can use these weights to calculate the national representative statistics about migrants' remittance behavior and household migration pattern, as we summarized in Table A.1.

To construct the share of household moving together, we first determine the employment status of each family member. We classify a migrant as employed if he or she is in a working status. Thus, we know the number of households (i.e., the number of observations, since each household chooses one representative to answer the questionnaire) and the number of employees within each household. In this way, we construct the share of households moving together as the ratio of the total number of households with more than one employee to the number of households with at least one employee.

One challenge for constructing the share of total remittance in total migrants' income is that the respondents are only required to report the amount of remittance sent by themselves and the household total income in the destination city. Therefore, we have no direct information on the remittance sent by other family members and the respondent's income. We solve this problem by calculating the average income per worker within each household. In detail, we first divide the total household income by the number of employments within the household and thus we obtain the inferred income for the respondent migrant; then we aggregate the remittance and inferred income for all respondents. Based on this treatment, we restrict our sample to all respondents, and define the share of remittance in total migrants' income as the ratio of total remittance to total income. Accordingly, we calculate migrants' probability of remitting as the ratio of the number of respondents sending positive remittances to the total number of respondents.

Table A.1: Summary Statistics on Migrants' Remittance Behavior and Household Migration Pattern

Description	Value
Probability of remitting	0.730
For remitter: share of remittance in income	0.193
For all migrants: share of remittance in income	0.142
Share of households with one adult worker	0.440
Share of households with two adult workers	0.495
Share of households with more than two adult workers	0.065

Notes: We define the probability of remitting as the ratio of the number of migrants sending positive remittances to the total number of migrants. The share of remittance in income is the ratio of total remittance to total migrants' income: in the second row, we restrict our sample to remitters; in the third row, the sample includes all migrants. The share of households with one adult worker is calculated by the ratio of the number of households with only one adult worker to the number of households with at least one adult worker. The share of households with two adult workers (with more than two adult workers) is calculated by the ratio of the number of households with two adult workers (with more than two adult workers) to the number of households with at least one worker. The household here only considers the household with migrants and is destination-city-based. We restrict our sample to migrants who are currently working when summarizing the household migration pattern. All these variables are calculated using CMDS data.

A.2 Additional Results using CHIP

In this section, we use the Chinese Household Income Project (CHIP) survey data to present additional results about migrants' remittance behavior. The CHIP dataset is collected through a series of questionnaire-based interviews conducted in rural and urban areas. We focus on the Rural-Urban Migrant module and use the data in 2007 and 2008 since these two waves contain information about migrants' households and the use of remittance. The module covers 5,000 rural-to-urban migrant individuals randomly sampled from 15 major urban destinations in China.[26] We focus on three questions: "income from being employed" to gather detailed data about migrants' wage income; "how much did you remit to your home village?" to determine the amount of migrant's remittance; "the uses of remittance" to infer the motives of sending remittance.

According to the data, the use of remittances can be classified mostly as household consumption. Table A.2 lists the main uses of remittances. For 52% of migrants who send remittances, supporting family members' daily expenses is the most important use. Expenditure on children's education and housing construction can also be regarded as consumption, with 12% and 4% of migrants reporting them as the most important use of the transfer, respectively.

We provide more evidence of factors affecting migrants' remittance behavior based on the CHIP data. One challenge in examining the effect of the stayers' income is that, in the survey,

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[26] The list of cities is: Shanghai; Guangzhou, Dongguan and Shenzhen (Guangdong province); Nanjing and Wuxi (Jiangsu Province); Hangzhou and Ningbo (Zhejiang province) ; Wuhan (Hubei province); Hefei and Bengbu (Anhui province); Zhengzhou and Luoyang (Henan province); Chongqing; Chengdu (Sichuan province).

we do not know migrants' home regions, and migrants do not report the average income in their home region. The only available information is the self-estimated income of migrants had they stayed in their home villages. This variable contains information on the income level in the migrant's hometown as well as the earning power of the migrant. Table A.3 reports the results. The amount of remittances increases with migrants' income and decreases with the reported minimal living expenditure and the number of family members in the cities.

In CHIP, we do not have a good proxy for the income of the left-behind family members. In the regressions, we control for the reported income of the migrant if he/she did not migrate. We find a positive or zero effect of this variable on remittances. It is possible that this measure is a poor proxy for the demand for income of left-behind family members. For example, migrants who expect strong wage growth in the future may remit more, and such expectations may not be captured by their current income but can be correlated with their unobserved ability, which may be picked by their reported income if they did not migrate. We provide better evidence that family members' demand for income increases remittances in Section 2 using the CMDS data.

Table A.2: Use of Remittance

	First Choice (%)	All Choices (%)
Daily Expenses	52	34
Elderly Pension	25	31
Child Education Expenditure	12	14
Marriage Preparation	4	7
Housing	4	6
Others	2	7

Notes: Data source is the CHIP of 2007. Surveyed migrants are asked to choose the three most important uses of remittances and sort these uses from foremost to less important. Thus, each migrant has a first, second and third choice. The key variable here is the percentage of remitted migrants that send remittances for the corresponding usage. We summarized their first choice of uses in the first column, i.e., the foremost use of remittances. In the second column, we summarize all three choices.

Table A.3: Determinants of Remittances Using Alternative Dataset (CHIP 2007/2008)

	(1) log(remittance)	(2) log(1 + remittance)	(3)) $\mathbf{1}$(remittance > 0)
log(Migrant's Income)	0.638^a	1.617^a	0.154^a
	(0.042)	(0.100)	(0.011)
log(Migrant's Minimal Living Expenditure)	-0.106^a	-0.379^a	-0.040^a
	(0.025)	(0.070)	(0.009)
No. of Family Members Moving Together	-0.247^a	-0.542^a	-0.051^a
	(0.023)	(0.057)	(0.007)
log(Income at Hometown If Not Migrate)	0.132^a	-0.023	-0.013
	(0.023)	(0.064)	(0.008)
Year FE	Yes	Yes	Yes
City FE	Yes	Yes	Yes
Observations	5748	9298	9302
R^2	0.167	0.082	0.063

Notes: Data source is the CHIP of 2007 and 2008 since only these two waves include information related to the estimated earnings of migrants if they still work in their hometown village. The dependent variables are the log of remittances measured in Chinese Yuan (or one plus remittance values) or an indicator of whether the migrant sends remittances back to his/her home village. Year and destination city fixed effects are controlled. Robust standard errors are in parentheses. Significance levels: c 0.1, b 0.05, a 0.01.

B Additional Theoretical Results

B.1 Aggregate Expenditure Share

By maximizing the problem in equation (1), we obtain the following individual ω's expenditure in goods j:

$$\alpha^j\big(\frac{P_n^j}{P_n}\big)^{1-\varsigma}v_n(\omega)+\alpha_j\big(\frac{P_n^j}{P_n}\big)^{1-\varsigma}\sum_{k\in\{A,M,S\}}P_n^k\bar{c}^k-P_n^j\bar{c}^j,$$

where $v_n(\omega)$ is the income for this individual, and the subscript n denotes the region where he works. Aggregating the expenditure in goods j from all workers in region n, we have the regional total expenditure in goods j:

$$\alpha^j\big(\frac{P_n^j}{P_n}\big)^{1-\varsigma}E_n+\alpha_j\big(\frac{P_n^j}{P_n}\big)^{1-\varsigma}\sum_{k\in\{A,M,S\}}P_n^k\bar{c}^kL_n-P_n^j\bar{c}^jL_n,$$

where $E_n=\sum_\omega v_n(\omega)$ is the total income of all workers in region n, and L_n is the total population in region n.

Then, the aggregate expenditure share of goods j in region n is:

$$S_n^j=\alpha^j\big(\frac{P_n^j}{P_n}\big)^{1-\varsigma}+\frac{\alpha^j\big(\frac{P_n^j}{P_n}\big)^{1-\varsigma}\sum_{k\in\{A,M,S\}}P_n^k\bar{c}_n^k-P_n^j\bar{c}_n^j}{E_n},\tag{B.1}$$

where $\bar{c}^j_n = \bar{c}^j L_n$. The aggregate expenditure share can also be represented by a representative agent with average income $\bar{v}_n$, that is:

$$S^j_n = \alpha^j \left(\frac{P^j_n}{P_n}\right)^{1-\varsigma} + \frac{\alpha^j \left(\frac{P^j_n}{P_n}\right)^{1-\varsigma} \sum_{k\in\mathcal{J}} P^k_n \bar{c}^k - P^j_n \bar{c}^j}{\bar{v}_n}. \tag{B.2}$$

B.2 Proof of Proposition 1

Situation 1: Both stay at home or move together

In this situation, Member 1 and Member 2 either stay in their hometown or migrate together. Taking the log of equation (8), we rewrite the optimization problem as

$$\max_{T_1,T_2} \log U = \lambda_1 \log(I_1 - T_1) + \lambda_2 \log(I_2 - T_2) + \lambda_3 \log(I_3 + T_1 + T_2),\ s.t.,\ T_1 + T_2 \geq 0.$$

The Lagrangian in this case is

$$L(T_1, T_2, \rho) = \lambda_1 \log(I_1 - T_1) + \lambda_2 \log(I_2 - T_2) + \lambda_3 \log(I_3 + T_1 + T_2) + \rho(T_1 + T_2),$$

and the Karush-Kuhn-Tucker (KKT) conditions are

$$\begin{aligned}
\frac{-\lambda_1}{I_1 - T_1} + \frac{\lambda_3}{I_3 + T_1 + T_2} + \rho &= 0,\\
\frac{-\lambda_2}{I_2 - T_2} + \frac{\lambda_3}{I_3 + T_1 + T_2} + \rho &= 0,\\
\rho(T_1 + T_2) &= 0,\\
T_1 + T_2 &\geq 0,\\
\rho &\geq 0.
\end{aligned}$$

We consider two cases:
Case 1. $\rho = 0$. In this case our system becomes

$$\begin{aligned}
\frac{-\lambda_1}{I_1 - T_1} + \frac{\lambda_3}{I_3 + T_1 + T_2} &= 0,\\
\frac{-\lambda_2}{I_2 - T_2} + \frac{\lambda_3}{I_3 + T_1 + T_2} &= 0,\\
0 &= 0,\\
T_1 + T_2 &\geq 0, \qquad \text{(B.4a)}\\
0 &= 0.
\end{aligned}$$

Solving the first two equations together with the condition (B.4a), we have the optimal remittance

$$\begin{aligned} T_1^* &= (1-\lambda_1)I_1 - \lambda_1 I_2 - \lambda_1 I_3 \\ T_2^* &= (1-\lambda_2)I_2 - \lambda_2 I_1 - \lambda_2 I_3, \end{aligned}$$

when $I_1 + I_2 \geq (\lambda_1 + \lambda_2)(I_1 + I_2 + I_3)$ holds.

Case 2. $T_1 + T_2 = 0$. In this case our system becomes

$$\begin{aligned} \frac{-\lambda_1}{I_1 - T_1} + \frac{\lambda_3}{I_3 + T_1 + T_2} + \rho &= 0, \\ \frac{-\lambda_2}{I_2 - T_2} + \frac{\lambda_3}{I_3 + T_1 + T_2} + \rho &= 0, \\ 0 &= 0, \\ T_1 + T_2 &= 0, \\ \rho &\geq 0. \end{aligned}$$

Solving the system we have

$$\begin{aligned} T_1^* &= \frac{\lambda_2 I_1 - \lambda_1 I_2}{\lambda_1 + \lambda_2} \\ T_2^* &= \frac{\lambda_1 I_2 - \lambda_2 I_1}{\lambda_1 + \lambda_2} \\ \rho &= \frac{(\lambda_1 + \lambda_2)I_3 - \lambda_3(I_1 + I_2)}{I_3(I_1 + I_2)}, \end{aligned}$$

and the optimal remittance (T_1^*, T_2^*) in this case exists when $\rho \geq 0$ holds, that is,

$$I_1 + I_2 \leq (\lambda_1 + \lambda_2)(I_1 + I_2 + I_3).$$

To sum up, when Member 1 and 2 stay in the same place, Member 3 receives positive transfers from these two members if the share of Member 1 and 2's aggregate income in total household income is larger than the sum of these two members' utility weights. Otherwise, Member 2 and Member 1 only transfer to each other and thus no transfers send to Member 3.

Situation 2: One stays at home, and one moves out

In this scenario, Member 1 stays in his hometown while Member 2 migrates. The optimization problem is

$$\max_{T_1, T_2} \log U = \lambda_1 \log(I_1 - T_1) + \lambda_2 \log(I_2 - T_2) + \lambda_3 \log(I_3 + T_1 + T_2), \; s.t., \; T_1 + T_2 \geq 0, \; T_2 \geq 0.$$

The Lagrangian in this scenario is

$$L(T_1, T_2, \rho_1, \rho_2) = \lambda_1 \log(I_1 - T_1) + \lambda_2 \log(I_2 - T_2) + \lambda_3 \log(I_3 + T_1 + T_2) + \rho_1(T_1 + T_2) + \rho_2 T_2,$$

and the KKT conditions are

$$\begin{aligned}
\frac{-\lambda_1}{I_1 - T_1} + \frac{\lambda_3}{I_3 + T_1 + T_2} + \rho_1 &= 0, \\
\frac{-\lambda_2}{I_2 - T_2} + \frac{\lambda_3}{I_3 + T_1 + T_2} + \rho_1 + \rho_2 &= 0, \\
\rho_1(T_1 + T_2) &= 0, \\
T_1 + T_2 &\geq 0, \\
\rho_2 T_2 &= 0, \\
T_2 &\geq 0, \\
\rho_1 &\geq 0, \\
\rho_2 &\geq 0.
\end{aligned}$$

We consider four cases: **Case 1.** $\rho_1 = 0$ and $\rho_2 = 0$. In this case, the system becomes

$$\begin{aligned}
\frac{-\lambda_1}{I_1 - T_1} + \frac{\lambda_3}{I_3 + T_1 + T_2} &= 0, \\
\frac{-\lambda_2}{I_2 - T_2} + \frac{\lambda_3}{I_3 + T_1 + T_2} &= 0, \\
0 &= 0, \\
T_1 + T_2 &\geq 0, \\
0 &= 0, \\
T_2 &\geq 0, \\
\rho_1 &= 0, \\
\rho_2 &= 0.
\end{aligned}$$

Solve the system, we have the solution that

$$\begin{aligned}
T_1^* &= (1 - \lambda_1)I_1 - \lambda_1 I_2 - \lambda_1 I_3, \\
T_2^* &= (1 - \lambda_2)I_2 - \lambda_2 I_1 - \lambda_2 I_3,
\end{aligned}$$

when conditions $T_1 + T_2 \geq 0$ and $T_2 \geq 0$ hold, which means

$$I_1 + I_2 \geq (\lambda_1 + \lambda_2)(I_1 + I_2 + I_3),$$

$$I_2 \geq \lambda_2(I_1 + I_2 + I_3).$$

That is, Member 2 sends remittance to the other two family members once the share of his income in the total household income is no less than his utility weight.

Case 2. $\rho_1 = 0$ and $T_2 = 0$. In this case, the system becomes

$$\begin{aligned}
\frac{-\lambda_1}{I_1 - T_1} + \frac{\lambda_3}{I_3 + T_1 + T_2} &= 0, \\
\frac{-\lambda_2}{I_2 - T_2} + \frac{\lambda_3}{I_3 + T_1 + T_2} + \rho_2 &= 0, \\
0 &= 0, \\
T_1 + T_2 &\geq 0, \\
0 &= 0, \\
T_2 &= 0, \\
\rho_1 &= 0, \\
\rho_2 &\geq 0.
\end{aligned}$$

Solving this system, we have

$$\begin{aligned}
T_1^* &= \frac{\lambda_3 I_1 - \lambda_1 I_3}{\lambda_1 + \lambda_3} \\
T_2^* &= 0 \\
\rho_2 &= \frac{\lambda_2}{I_2} - \frac{\lambda_1 + \lambda_3}{I_1 + I_3}
\end{aligned}$$

where $\rho_2 \geq 0$ implies that $I_2 \leq \lambda_2(I_1 + I_2 + I_3)$; and $T_1 + T_2 \geq 0$ implies that $I_1 \geq \frac{\lambda_1}{\lambda_1 + \lambda_3}(I_1 + I_3)$. In this case, Member 2 sends zero remittance because the share of his income in the total household income is no greater than his utility weight. Moreover, Member 1 transfers to Member 3 only if the share of his income in the total income of left-behind family members is greater than the share of his utility weight in the sum of left-behind members' weights.

Case 3. $T_1 + T_2 = 0$ and $\rho_2 = 0$. In this case, the system is

$$\begin{aligned}
\frac{-\lambda_1}{I_1 - T_1} + \frac{\lambda_3}{I_3 + T_1 + T_2} + \rho_1 &= 0, \\
\frac{-\lambda_2}{I_2 - T_2} + \frac{\lambda_3}{I_3 + T_1 + T_2} + \rho_1 &= 0, \\
0 &= 0, \\
T_1 + T_2 &= 0, \\
0 &= 0,
\end{aligned}$$

$$
\begin{aligned}
T_2 &\geq 0,\\
\rho_1 &\geq 0,\\
\rho_2 &= 0.
\end{aligned}
$$

Solving the system, we have

$$
\begin{aligned}
T_1^* &= \frac{\lambda_2 I_1 - \lambda_1 I_2}{\lambda_1 + \lambda_2}\\
T_2^* &= \frac{\lambda_1 I_2 - \lambda_2 I_1}{\lambda_1 + \lambda_2}\\
\rho_1 &= \frac{(\lambda_1 + \lambda_2) I_3 - \lambda_3 (I_1 + I_2)}{I_3 (I_1 + I_2)}
\end{aligned}
$$

where $\rho_1 \geq 0$ implies that $I_1 + I_2 \leq (\lambda_1 + \lambda_2)(I_1 + I_2 + I_3)$; and $T_2 \geq 0$ implies that $I_2 \geq \frac{\lambda_2}{\lambda_1+\lambda_2}(I_1 + I_2)$. In this case, Member 3 receives zero transfer from other members while Member 1 receive the remittance from Member 2.

Case 4. $T_1 + T_2 = 0$ and $T_2 = 0$.

$$
\begin{aligned}
\frac{-\lambda_1}{I_1 - T_1} + \frac{\lambda_3}{I_3 + T_1 + T_2} + \rho_1 &= 0,\\
\frac{-\lambda_2}{I_2 - T_2} + \frac{\lambda_3}{I_3 + T_1 + T_2} + \rho_1 + \rho_2 &= 0,\\
0 &= 0,\\
T_1 + T_2 &= 0,\\
0 &= 0,\\
T_2 &= 0,\\
\rho_1 &\geq 0,\\
\rho_2 &\geq 0.
\end{aligned}
$$

In this case, $T_1^* = 0$ and $T_2^* = 0$. Solving the system, we have

$$
\begin{aligned}
\rho_1 &= \frac{\lambda_1}{I_1} - \frac{\lambda_3}{I_3}\\
\rho_2 &= \frac{\lambda_2}{I_2} - \frac{\lambda_1}{I_2}
\end{aligned}
$$

and the conditions $\rho_1 \geq 0$ and $\rho_2 \geq 0$ implies that if $I_1 \leq \frac{\lambda_1}{\lambda_1+\lambda_3}(I_1 + I_3)$ and $I_2 \leq \frac{\lambda_2}{\lambda_1+\lambda_2}(I_1 + I_2)$, no intra-household transfers within this family.

B.3 Proof of Corollary 1

In Situation 1 with Member 1 and Member 2 staying at the same place, the optimal remittances $\{T_1^*, T_2^*\}$ are continuous at the cut-off conditions, i.e., $I_1 + I_2 = (\lambda_1 + \lambda_2)(I_1 + I_2 + I_3)$. Therefore, for Case 1, taking the derivative of $\{T_1^*, T_2^*\}$ with respect to $\{I_1, I_2, I_3, \lambda_1, \lambda_2, \lambda_3\}$, we have

$$
\begin{array}{llllll}
\frac{\partial T_1^*}{\partial I_1} > 0, & \frac{\partial T_1^*}{\partial I_2} < 0, & \frac{\partial T_1^*}{\partial I_3} < 0, & \frac{\partial T_1^*}{\partial \lambda_1} < 0, & \frac{\partial T_1^*}{\partial \lambda_2} = 0, & \frac{\partial T_1^*}{\partial \lambda_3} = 0, \\
\frac{\partial T_2^*}{\partial I_1} < 0, & \frac{\partial T_2^*}{\partial I_2} > 0, & \frac{\partial T_2^*}{\partial I_3} < 0, & \frac{\partial T_2^*}{\partial \lambda_1} = 0, & \frac{\partial T_2^*}{\partial \lambda_2} < 0, & \frac{\partial T_1^*}{\partial \lambda_3} = 0.
\end{array}
$$

Similarly, we have the following first-order conditions under Case 2:

$$
\begin{array}{llllll}
\frac{\partial T_1^*}{\partial I_1} > 0, & \frac{\partial T_1^*}{\partial I_2} < 0, & \frac{\partial T_1^*}{\partial I_3} = 0, & \frac{\partial T_1^*}{\partial \lambda_1} < 0, & \frac{\partial T_1^*}{\partial \lambda_2} > 0, & \frac{\partial T_1^*}{\partial \lambda_3} = 0, \\
\frac{\partial T_2^*}{\partial I_1} < 0, & \frac{\partial T_2^*}{\partial I_2} > 0, & \frac{\partial T_2^*}{\partial I_3} = 0, & \frac{\partial T_2^*}{\partial \lambda_1} > 0, & \frac{\partial T_2^*}{\partial \lambda_2} < 0, & \frac{\partial T_2^*}{\partial \lambda_3} = 0.
\end{array}
$$

In Situation 2, with only Member 2 migrating while Member 1 staying in his hometown, we can easily obtain that the optimal remittances $\{T_1^*, T_2^*\}$ are continuous at the cut-off conditions. Then, taking the derivative of $\{T_1^*, T_2^*\}$ with respect to $\{I_1, I_2, I_3, \lambda_1, \lambda_2\}$ under all cases, we can summarize the first-order conditions as

$$
\begin{array}{llllll}
\frac{\partial T_1^*}{\partial I_1} \geq 0, & \frac{\partial T_1^*}{\partial I_2} \leq 0, & \frac{\partial T_1^*}{\partial I_3} \leq 0, & \frac{\partial T_1^*}{\partial \lambda_1} \leq 0, & \frac{\partial T_1^*}{\partial \lambda_2} \geq 0, & \frac{\partial T_1^*}{\partial \lambda_3} \geq 0, \\
\frac{\partial T_2^*}{\partial I_1} \leq 0, & \frac{\partial T_2^*}{\partial I_2} \geq 0, & \frac{\partial T_2^*}{\partial I_3} \leq 0, & \frac{\partial T_2^*}{\partial \lambda_1} \geq 0, & \frac{\partial T_2^*}{\partial \lambda_2} \leq 0, & \frac{\partial T_1^*}{\partial \lambda_3} \geq 0.
\end{array}
$$

To sum up, given the property of first-order conditions under all possible situations, we can conclude that the optimal transfers $\{T_1^*, T_2^*\}$ are weakly increasing in the income of the focal family member and weakly decreasing in the income of the other members. Moreover, the optimal transfers weakly decreasing in the utility weight of the focal family member and are weakly increasing in the weights of other family members.

B.4 Optimal Transfer When Migrants' Remittances are Banned

Situation 1: Member 1 and Member 2 both stay at their hometown. In this situation, no migration happens within the household. The intra-household transfers across Member 1 and Member 2 to Member 3 are the same as the similar scenario in Appendix B.2. Therefore, if $I_1 + I_2 \geq (\lambda_1 + \lambda_2)(I_1 + I_2 + I_3)$,

$$
T_1^* = (1 - \lambda_1)I_1 - \lambda_1 I_2 - \lambda_1 I_3; \quad T_2^* = (1 - \lambda_2)I_2 - \lambda_2 I_1 - \lambda_2 I_3;
$$

else,

$$T_1^* = \frac{\lambda_2 I_1 - \lambda_1 I_2}{\lambda_1 + \lambda_2}; \quad T_2^* = \frac{\lambda_1 I_2 - \lambda_2 I_1}{\lambda_1 + \lambda_2}.$$

Situation 2: Member 1 and Member 2 move out together. In this situation, both members are migrants. Although transfers to Member 3 are banned, Members 1 and 2 can transfer money to each other. Therefore, the optimization problem changes to

$$\max_{T_1,T_2} \log U = \lambda_1 \log(I_1 - T_1) + \lambda_2 \log(I_2 - T_2) + \lambda_3 \log(I_3 + T_1 + T_2), \ s.t., \ T_1 + T_2 = 0.$$

Solving this problem, we have

$$\begin{aligned} T_1^* &= \frac{\lambda_2 I_1 - \lambda_1 I_2}{\lambda_1 + \lambda_2} \\ T_2^* &= \frac{\lambda_1 I_2 - \lambda_2 I_1}{\lambda_1 + \lambda_2}. \end{aligned}$$

Situation 3: Member 2 moves out alone. In this situation, Member 1 stays in his hometown, while Member 2 move out alone. Although we ban the transfers from Member 2, Member 1 can transfer money to support Member 3. The optimization problem in this situation is

$$\max_{T_1,T_2} \log U = \lambda_1 \log(I_1 - T_1) + \lambda_2 \log(I_2 - T_2) + \lambda_3 \log(I_3 + T_1 + T_2), \ s.t., \ T_1 \geq 0, \ T_2 = 0.$$

Solving this problem, we have

$$\begin{aligned} T_1^* &= \frac{\lambda_3 I_1 - \lambda_1 I_3}{\lambda_1 + \lambda_3}, && \text{if } I_1 \geq \frac{\lambda_1}{\lambda_1 + \lambda_3}(I_1 + I_3); \\ T_1^* &= 0, && \text{if } I_1 < \frac{\lambda_1}{\lambda_1 + \lambda_3}(I_1 + I_3). \end{aligned}$$

B.5 Household Expected Utility

Given that the idiosyncratic household preference over workplaces and sectors, b_{ni}^{kj}, is drawn from a Fréchet distribution $F_{ni}^{kj}(b) = e^{-B_{ni}^{kj} b^{-\epsilon}}$, we first show that the indirect utility function for a household from region o with *Hukou* type $\mathcal{H} \in \{\mathcal{R}, \mathcal{U}\}$

$$U_{o,ni}^{\mathcal{H},kj} = \frac{b_{ni}^{kj} u_{o,ni}^{\mathcal{H},kj}}{\kappa_{ni} (\mu_{on}^{\mathcal{H},k})^{\lambda_1} (\mu_{oi}^{\mathcal{H},j})^{\lambda_2}}$$

also has a Fréchet distribution:

$$\begin{aligned}
\Pr\left[U_{o,ni}^{\mathcal{H},kj} \leq U\right] &= \Pr\left[\frac{b_{ni}^{kj} u_{o,ni}^{\mathcal{H},kj}}{\kappa_{ni}(\mu_{on}^{\mathcal{H},k})^{\lambda_1}(\mu_{oi}^{\mathcal{H},j})^{\lambda_2}} \leq U\right] \\
&= \Pr\left[b_{ni}^{kj} \leq \frac{U\kappa_{ni}(\mu_{on}^{\mathcal{H},k})^{\lambda_1}(\mu_{oi}^{\mathcal{H},j})^{\lambda_2}}{u_{o,ni}^{\mathcal{H},kj}}\right] \\
&= e^{-B_{ni}^{kj}\left(\frac{u_{o,ni}^{\mathcal{H},kj}}{\kappa_{ni}(\mu_{on}^{\mathcal{H},k})^{\lambda_1}(\mu_{oi}^{\mathcal{H},j})^{\lambda_2}}\right)^{\epsilon} U^{-\epsilon}}.
\end{aligned}$$

Therefore, we have $F_{o,ni}^{\mathcal{H},kj}(U) = e^{-\psi_{o,ni}^{\mathcal{H},kj} U^{-\epsilon}}$, where $\psi_{o,ni}^{\mathcal{H},kj} = B_{ni}^{kj}\left(\frac{u_{o,ni}^{\mathcal{H},kj}}{\kappa_{ni}(\mu_{on}^{\mathcal{H},k})^{\lambda_1}(\mu_{oi}^{\mathcal{H},j})^{\lambda_2}}\right)^{\epsilon}$.

Accordingly, the expected utility for a household from region o with *Hukou* type $\mathcal{H} \in \{\mathcal{R}, \mathcal{U}\}$ is

$$\begin{aligned}
\bar{U}_{o,ni}^{\mathcal{H},kj} &= \sum_{k',j' \in \mathcal{J}} \sum_{n',i' \in \mathcal{N}} \int_0^{\infty} \Pr\left[U_{o,n'i'}^{\mathcal{H},k'j'} \leq U\right] U \mathrm{d}F_{o,ni}^{\mathcal{H},kj}(U) \\
&= \Gamma\left(\frac{\epsilon - 1}{\epsilon}\right)\left[\sum_{k',j' \in \mathcal{J}} \sum_{n',i' \in \mathcal{N}} B_{n'i'}^{k'j'}\left(\frac{u_{o,n'i'}^{\mathcal{H},k'j'}}{\kappa_{n'i'}(\mu_{on'}^{\mathcal{H},k'})^{\lambda_1}(\mu_{oi'}^{\mathcal{H},j'})^{\lambda_2}}\right)^{\epsilon}\right]^{\frac{1}{\epsilon}}, \qquad \text{(B.11)}
\end{aligned}$$

where $\Gamma(\cdot)$ is the Gamma function.

C Additional Quantitative Results

C.1 Calibration of Input Shares

The input-output parameters are constructed using China's 2010 Input-Output Table. One issue is that the physical capital is excluded from our model, and thus the input share should be the share of gross output net of physical capital. To solve this issue, we follow Tombe and Zhu (2019) to transform the production function to be net of physical capital. Specifically, if the production technologies are

$$Y = \tilde{A} L^{\tilde{\beta}} H^{\tilde{\eta}} M^{\tilde{\gamma}} K^{\tilde{\alpha}},$$

where L, H, M and K stand for labor, land, intermediate input and capital, respectively, and $\tilde{\beta} + \tilde{\eta} + \tilde{\gamma} + \tilde{\alpha} = 1$. Then, the gross output net of physical capital can be written as

$$Y = A L^{\beta} H^{\eta} M^{\gamma},$$

where $\beta = \tilde{\beta}/(1 - \tilde{\alpha})$, $\eta = \tilde{\eta}/(1 - \tilde{\alpha})$, and $\gamma = \tilde{\gamma}/(1 - \tilde{\alpha})$. Therefore, the value of $\{\beta, \eta, \gamma\}$ can be inferred from the value added share of gross output, $\tilde{\beta} + \tilde{\eta} + \tilde{\alpha}$, and labor's and land's share of value added, i.e., $\tilde{\beta}/(\tilde{\beta}+\tilde{\eta}+\tilde{\alpha})$, $\tilde{\eta}/(\tilde{\beta}+\tilde{\eta}+\tilde{\alpha})$ and $\tilde{\alpha}/(\tilde{\beta}+\tilde{\eta}+\tilde{\alpha})$.

We begin with $\tilde{\alpha}$. We follow the assumption in Tombe and Zhu (2019) that land returns are allocated to labor in the agricultural sector but to operating surpluses in the manufacturing and services sectors. Therefore, in our data, the non-labor's share of output in the agriculture sector is the capital's share, and we still have to net out the land's share for non-agricultural sectors. To do so, we assume land's share of value-added is 0.06 in non-agricultural sectors, the same value as in Tombe and Zhu (2019). Then, we have $\tilde{\alpha}^A = 0.03$, $\tilde{\alpha}^M = 0.12$ and $\tilde{\alpha}^S = 0.27$.

We next consider $\tilde{\beta}$ and $\tilde{\eta}$. In our data, the share of value-added in gross output is 0.58 in agriculture, 0.22 in manufacturing, and 0.55 in services. As mentioned, the input-output table allocates land returns to labor compensation in agriculture. The labor's share of value-added in China's agricultural sector is estimated to be 0.46 by Adamopoulos et al. (2017). Combining this value with our data, we have land's share of value-added equals 0.49.[27] Thus, together with our estimates for $\tilde{\alpha}$, we have $\beta^A = 0.46 \times 0.58/(1-0.03) \approx 0.28$ and $\eta^A = 0.49 \times 0.58/(1-0.03) \approx 0.29$. For manufacturing, we have $\beta^M = 0.39 \times 0.22/(1-0.12) \approx 0.10$ and $\eta^M = 0.06 \times 0.22/(1-0.12) \approx 0.02$; for the services sector, we have $\beta^S = 0.45 \times 0.55/(1-0.27) \approx 0.34$ and $\eta^S = 0.06 \times 0.55/(1-0.27) \approx 0.05$.

Finally, input-output shares are directly computed from our data. Intermediate input's shares of gross output are as in Table C.4. Dividing all $\tilde{\gamma}$ by the corresponding $1-\tilde{\alpha}$ and combining all the estimated results, we have the input-output matrix as in Table C.5.

Table C.4: Input Shares of Gross Output

$\tilde{\gamma}$	Output Industry		
Input	A	M	S
A	0.13	0.05	0.01
M	0.22	0.63	0.24
S	0.06	0.11	0.20

Table C.5: Input Shares of Gross Output Net of Physical Capital

	Output Industry		
Input	A	M	S
L	0.28	0.10	0.34
H	0.29	0.02	0.05
A	0.14	0.05	0.02
M	0.22	0.71	0.32
S	0.07	0.12	0.27

---

[27] We can compute capital's share of value-added from: $0.03/0.58 \approx 0.05$; thus, land's share of value added is $1-0.05-0.46 = 0.49$.

C.2 Normalization of Productivities

In this subsection, we show that the normalization of productivities in our model delivers an equivalent equilibrium as long as the conditions are satisfied. Here, we denote $\hat{x} = x'/x$ as the equilibrium relative change in variable x in response to some changes in model parameters.

Proposition C.1. *The normalization of productivities A_n^j delivers an equivalent equilibrium after the model is calibrated to the same set of moments if the values of $\alpha^{j\prime}$ and $\bar{c}^{j\prime}$ satisfy:*

$$\alpha^{j\prime} = \frac{\alpha^j (\hat{P}^j)^{\varsigma-1}}{\sum_j \alpha^j (\hat{P}^j)^{\varsigma-1}}, \quad \bar{c}^{j\prime} = \frac{\bar{c}^j}{\hat{P}^j}.$$

Proof. We prove this result using a guess-and-verify strategy. Suppose we rescale productivity A_n^j across all locations such that $\hat{A}_n^j = \hat{A}^j, \forall n$. To maintain the same factor prices($\hat{w}_n^j = 1,\ \hat{r}_n = 1$) and labor allocations($\hat{L}_n^j = 1$), the changes in the unit costs should satisfy $\hat{c}_n^j = \hat{c}^j$ (which means $\hat{\pi}_{ni}^j = 1$ and $\hat{P}_n^j = \hat{P}^j$) and the changes in consumers' expenditure share satisfy $\hat{S}_n^j = \hat{S}^j$.

We first prove that the changes in the unit costs are nation-wide, i.e., $\hat{c}_n^j = \hat{c}^j$. The relative changes of unit cost and price can be written as

$$\hat{c}_n^j = \prod_{k \in \mathcal{J}} (\hat{P}_n^k)^{\gamma^{jk}},$$
$$\hat{P}_n^j = (\hat{A}_n^j)^{\frac{1}{\theta}} \hat{c}_n^j.$$

Taking the log, we have

$$\log \hat{c}_n^j = \sum_k \gamma^{jk} \log \hat{P}_n^k = \sum_k \gamma^{jk} (-\frac{1}{\theta} \log \hat{A}_n^k + \log \hat{c}_n^k).$$

Expressing the changes of all sectors in a matrix form, we obtain

$$(I - \Omega) \log \hat{c}_n = -\frac{1}{\theta} \Omega \log \hat{A}_n,$$

where $\Omega = \left\{\gamma^{jk}\right\}_{j,k}$, $\log \hat{c}_n = \begin{bmatrix} \log \hat{c}_n^A \\ \log \hat{c}_n^M \\ \log \hat{c}_n^N \end{bmatrix}$, $\log \hat{A}_n = \begin{bmatrix} \log \hat{A}_n^A \\ \log \hat{A}_n^M \\ \log \hat{A}_n^N \end{bmatrix}$. Therefore,

$$\log \hat{c}_n = -\frac{1}{\theta} (I - \Omega)^{-1} \Omega \log \hat{A}_n.$$

Because $\hat{A}_n^j = \hat{A}^j$ is not location specific, we can rewrite the above equation as

$$\log \hat{c} = -\frac{1}{\theta}(I - \Omega)^{-1}\Omega \log \hat{A}.$$

Thus, we have $\hat{c}_n^j = \hat{c}^j$, which means the relative change in c_n^j is nation-wide. The relative change of prices

$$\log \hat{P}_n = -\frac{1}{\theta}(I - \Omega)^{-1} \log \hat{A},$$

where $\log \hat{P}_n = \begin{bmatrix} \log \hat{P}_n^A \\ \log \hat{P}_n^M \\ \log \hat{P}_n^N \end{bmatrix}$, is also nation-wide, i.e., $\hat{P}_n^j = \hat{P}^j$.

However, under the non-homothetic Stone-Geary preference, the changes of A_n^j might lead to $S_n^{j\prime}$ different from S_n^j. To maintain the consumption share, one solution is to rescale α^j according to $\hat{P}^j$ such that $\sum_j \alpha^{j\prime} = 1$, and rescale $\bar{c}^j$ such that $\widehat{\bar{c}^j}\hat{P}^j = 1$. That is:

$$\alpha^{j\prime} = \frac{\alpha^j(\hat{P}^j)^{\varsigma-1}}{\sum_j \alpha^j(\hat{P}^j)^{\varsigma-1}}, \quad \widehat{\bar{c}^j} = \frac{1}{\hat{P}^j}. \tag{C.12}$$

To sum up, the normalization of productivity, A_n^j, delivers an equivalent equilibrium after the model is calibrated to the same set of moments if equation (C.12) satisfies.

□

Although we know how to maintain consumption shares according to the normalization of productivities, we do not know the original values of A_n^j and thus cannot pin down $\bar{c}^{j\prime}$ and $\alpha^{j\prime}$. We overcome this challenge in two steps. First, we use the data on total expenditures, i.e. taking consumption shares as given, to calibrate productivities. Normalization in this way will not lead to a different equilibrium. Once we calibrated all A_n^j, we know the model-implied prices. Second, based on equation (3), we can estimate $\bar{c}^j$ and α^j to match the consumption shares in the data. The estimated results are namely $\alpha^{j\prime}$ and $\bar{c}^{j\prime}$, which maintain the consumption when we rescale A_n^j.

C.3 Details on Mechanism Decomposition

We discuss the details of mechanism decomposition in this subsection. Given that the Stone-Geary preference (SG) captures all mechanisms, we can decompose the role of the first three mechanisms, i.e., unequal demand change, price effect and income effect, by changing the preference from SG to constant elasticity of substitution (CES) and Cobb-Douglas (CD) preference. Figure C.1 provides a graphical illustration of this decomposition.

In detail, we isolate the income effect by comparing the results of banning remittances under SG preference to those under CES preference. To do so, we adopt the CES preference and recalibrate the model to conduct the same counterfactual of banning remittances. The difference between the results of banning remittances in our baseline model ($\triangle SG$) and the results under CES ($\triangle CES$) reveals the income effect. Then, similar to the steps in isolating the income effect, we compare the results under CES preference ($\triangle CES$) to those under CD preference ($\triangle CD$) to obtain the price effect.

However, banning remittances will also change migrants' willingness to migrate and thus change the model's prediction on structural change. These effects will contaminate the size of the unequal demand change effect if we simply compare the results under CD preference when banning remittances (CD^1) to those under CD preference with remittances (CD^0). To accurately isolate the size of the unequal demand change mechanism, we first recalibrate a model with remittances under CD preferences (CD^0). Next, we solve a "fixed-migration no-remittance equilibrium" denoted by ($\overline{CD^1}$) by fixing the household migration pattern at the initial equilibrium level under CD preference (CD^0), banning remittances and then allowing workers to change their industries. Therefore, the difference between the "fixed-migration no-remittance equilibrium" $\overline{CD^1}$ and the equilibrium with remittance under CD preference CD^0 measures the magnitude of unequal demand change effect. Correspondingly, we can identify the migration effect by comparing the equilibrium under CD preference banning remittance (CD^1) to the "fixed-migration no-remittance equilibrium" ($\overline{CD^1}$).

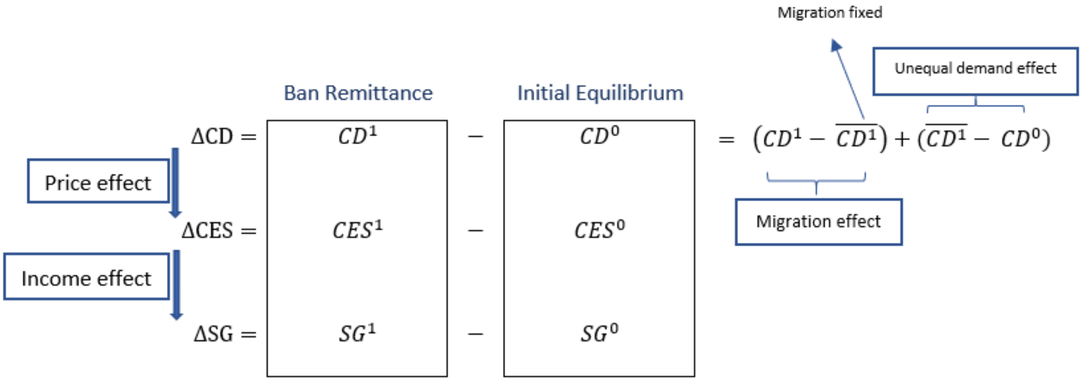
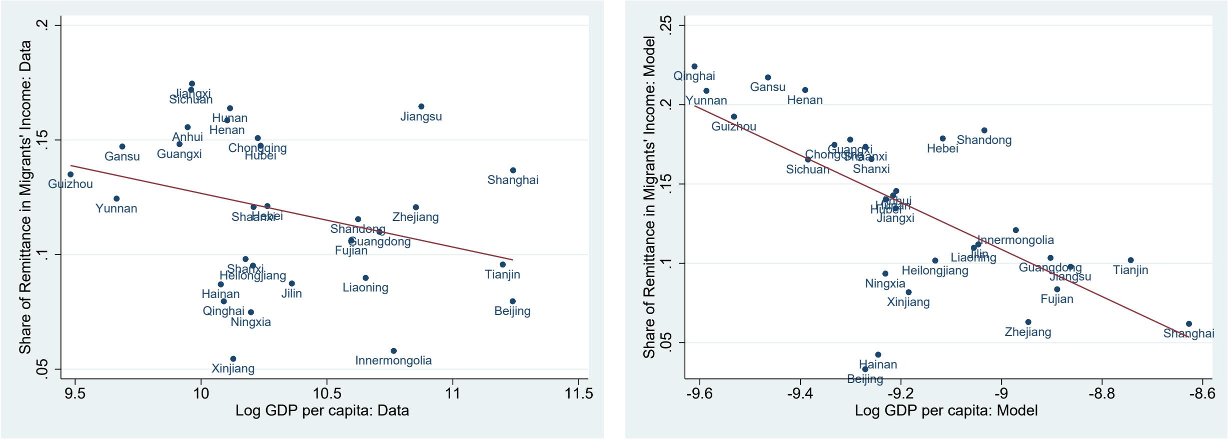


Figure C.1: Mechanism Decomposition

Notes: CD^1, CES^1 and SG^1 denote the equilibrium when banning remittances under CD, CES and SG preferences, respectively; CD^0, CES^0 and SG^0 denote the initial equilibrium with remittances under CD, CES and SG preferences, respectively; $\triangle CD$ measures the change from CD^1 to CD^0, and the meanings of $\triangle CES$ and $\triangle SG$ are similar. $\overline{CD^1}$ is the "fixed-migration no-remittance equilibrium" under CD preference. We solve this equilibrium by fixing the household migration pattern at the initial equilibrium level under CD preference (CD^0), banning remittances and then allowing workers to change their industries.

C.4 Additional Results

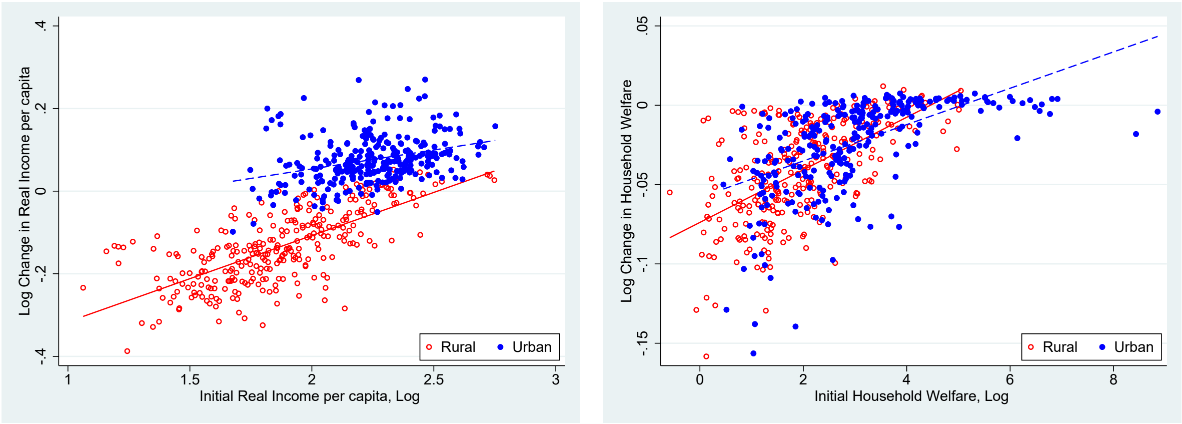


(a) Data

(b) Model

Figure C.2: Share of Remittance in Migrants' Income and GDP per capita, by Origin Province

Notes: These two figures plot the share of remittance in migrants' income against the GDP per capita (log) in the data and in the model, respectively. We calculate the shares based on the home province of the migrant. Each dot represents a province. The solid line through the dots is the linear fitted line. The slopes (with robust standard error) of the fitted lines are -0.023 (0.012) for Panel (a) and -0.148 (0.020) for Panel (b), respectively.



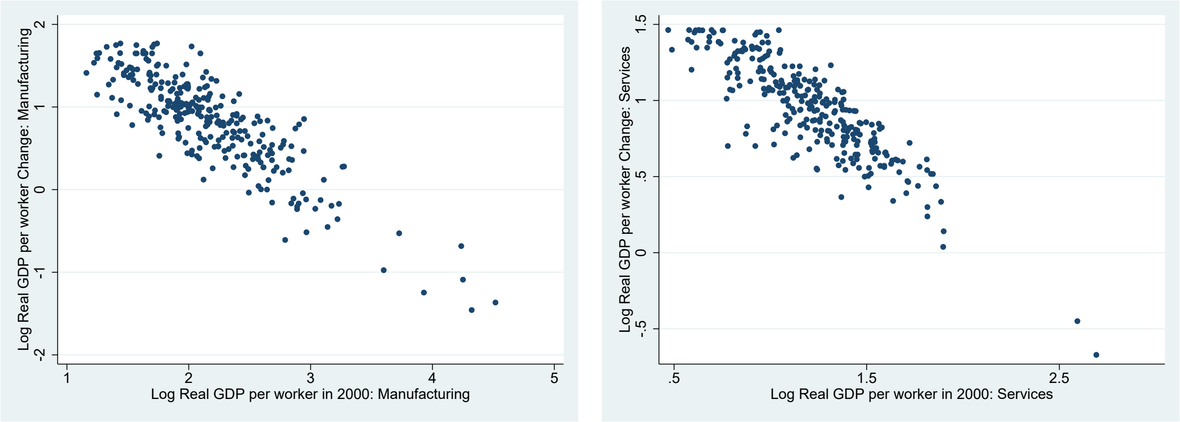
(a) Real Income

(b) Household Welfare

Figure C.3: Change in Log Real Income or Household Welfare after Banning Remittances

Notes: These two figures plot the change in log real income per capita (Panel (a)) or household welfare (Panel (b)) when banning remittance against their initial values in the benchmark with remittances. The hollow circles are for rural residents or households, while the solid circles are for urban residents or households. The slopes for the fitted lines (with robust standard error) in Panel (a) are: 0.21 (0.01) for rural; 0.09 (0.02) for urban. For Panel (b), the slopes for each linear fits (with robust standard error) in Panel (b) are: 0.02 (0.00) for rural; 0.01 (0.00) for urban. The positive slopes show an enlarging regional inequality. Meanwhile, the slope for rural is steeper either in terms of real income per capita or household welfare, indicating that rural residents or households suffer more from banning remittances.

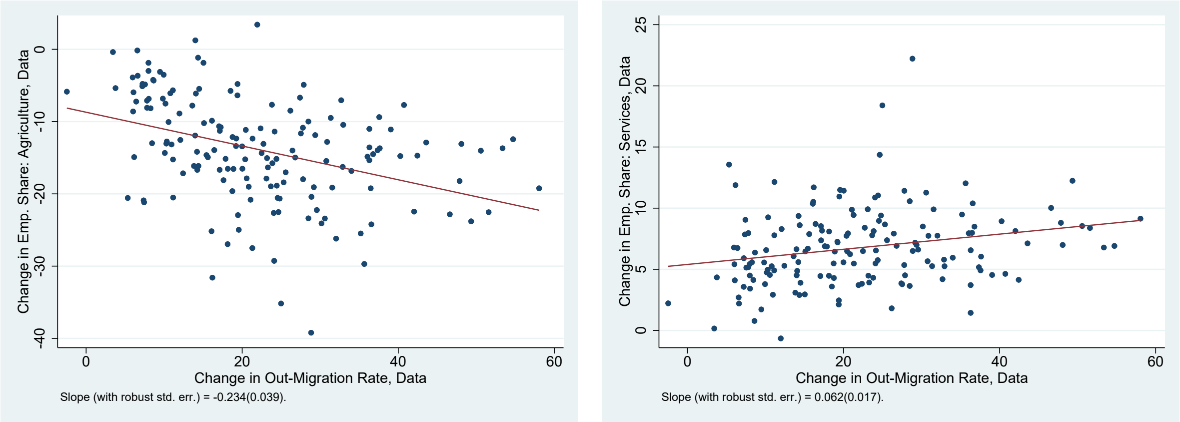
(a) Total (b) Agriculture



(c) Manufacturing (d) Services

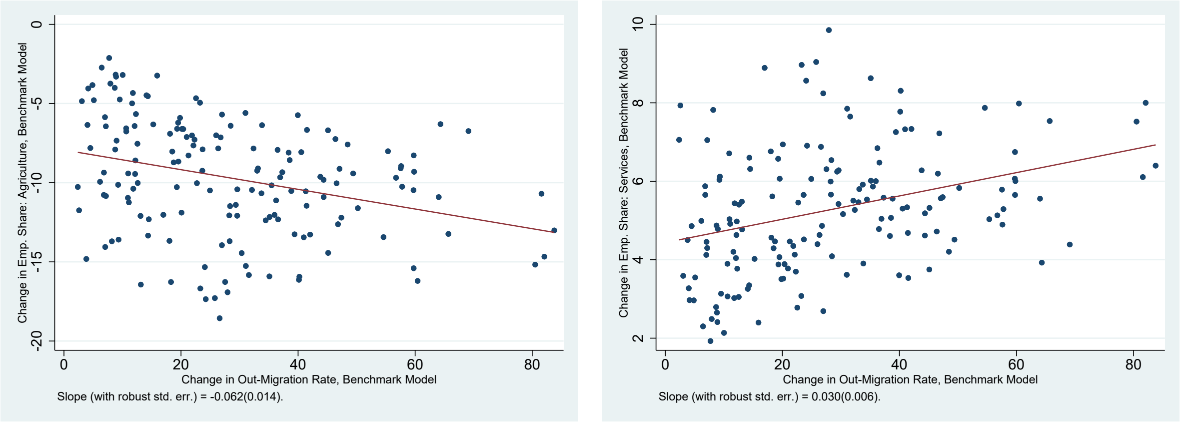
Figure C.4: Observed Change in Log Real GDP per worker, 2000 - 2010

Notes: These figures display the change in log real GDP per worker in total, agriculture, manufacturing and services from 2000 to 2010 against the corresponding initial log real GDP per worker in 2000. Each dot represents a city in China. The negative relationship in these figures implies a convergence across cities.



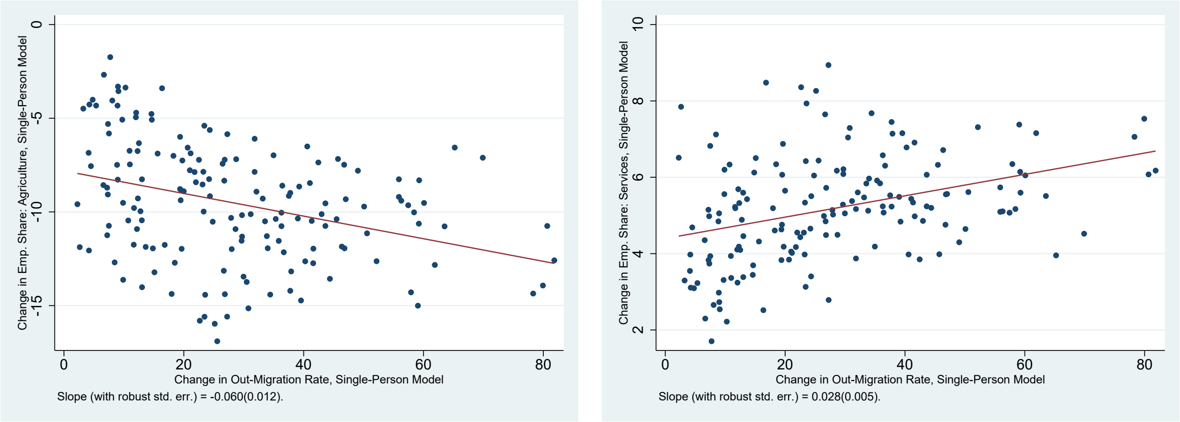
(a) Agriculture, Data

(b) Services, Data



(c) Agriculture, Benchmark Model

(d) Services, Benchmark Model



(e) Agriculture, Single-Person Model

(f) Services, Single-Person Model

Figure C.5: Out Migration and Structural Change

Notes: These figures display the change in agriculture and services employment shares against the change in the out-migration rate under different settings. Panels (a) and (b) show the corresponding changes in the data from 2000 to 2010. Panels (c) and (d) report the counterfactual changes, i.e., change the migration costs from the levels in 2000 to 2010, in our benchmark household model with remittance; Panels (c) and (d) plot the counterparts in the single-person model without remittance motives. We restrict the sample to cities with net population outflows in 2000. For each city, the out-migration rate is defined as the ratio of the number of outflow migrants to the total population. The slope (with robust standard error) of each fitted line is reported in the figure.

D Sensitivity Analysis

D.1 Price Independent Generalized Linearity (PIGL) Preference

An alternative choice for non-homothetic preference is the Price Independent Generalized Linearity (PIGL) specification. Here we follow the preference structure specified in Boppart (2014) that allows agricultural goods to be necessities, services to be luxuries and manufacturing to be neutrals. The indirect utility function for an individual working in region n with earnings e is

$$u(e, \mathbf{P_n}) = \frac{1}{\rho}\left[\frac{e}{\left((P_n^A)^{\phi}(P_n^S)^{1-\phi}\right)^{\alpha}(P_n^M)^{1-\alpha}}\right]^{\rho} - \frac{\eta}{\chi}\left[\frac{P_n^A}{P_n^S}\right]^{\chi}, \tag{D.13}$$

where $0 \leq \chi < 1$ governs the sensitivity of expenditure shares to changes in relative prices; $0 \leq \rho < 1$ governs the non-homotheticity between services and agriculture; $\eta > 0$ governs the importance of relative prices. Cobb-Douglas preference is a special case for PIGL when $\eta = 0$ and $\rho = 1$.

By using Roy's identity and aggregating the total demand of region n, we obtain the consumer expenditure shares in region n:

$$\begin{aligned} S_n^A &= \alpha\phi + \eta\left[\frac{P_n^A}{P_n^S}\right]^{\chi}\left[\frac{\bar{e}_n}{\left((P_n^A)^{\phi}(P_n^S)^{1-\phi}\right)^{\alpha}(P_n^M)^{1-\alpha}}\right]^{-\rho} \\ S_n^M &= 1-\alpha \\ S_n^S &= \alpha(1-\phi) - \eta\left[\frac{P_n^A}{P_n^S}\right]^{\chi}\left[\frac{\bar{e}_n}{\left((P_n^A)^{\phi}(P_n^S)^{1-\phi}\right)^{\alpha}(P_n^M)^{1-\alpha}}\right]^{-\rho}, \end{aligned} \tag{D.14}$$

where $\bar{e}_n = \left[\sum_{\omega}\frac{e_n(\omega)^{1-\rho}L_n(\omega)}{E_n}\right]^{-\frac{1}{\rho}}$ is the weighted average income and E_n is the total income of region n. The expenditure shares imply that: as income grows, the share allocated to agricultural goods decreases and converges to $\alpha\phi$; the share allocated to services goods increases and converges to $\alpha(1-\phi)$; the expenditure share on manufacturing goods is fixed.

Optimal Remittances To obtain the closed-form expression of optimal remittances, we assume the household indirect utility function (not taking into account idiosyncratic preference shocks and migration costs) as the weighted sum of each member's indirect utility. Thus, conditional on the location and sector choices of Member 1 and Member 2, these two members simultaneously decide their amount of intra-household transfers to solve the optimization problem

$$\max_{T_1,T_2} \lambda_1 u(I_1 - T_1, \mathbf{P_1}) + \lambda_2 u(I_2 - T_2, \mathbf{P_2}) + \lambda_3 u(I_3 + T_1 + T_2, \mathbf{P_3}),$$

subject to $T_1 + T_2 \geq 0$ if Member 1 and 2 stay in the same place; $T_1 + T_2 \geq 0$ and $T_2 \geq 0$ if Member 2 migrates alone. Note that the subscript here denotes the type of family members; I_1, I_2 and I_3 are the pre-transfer income of each member, and T_1 and T_2 are the amount of transfers sent from Members 1 and Member 2. Solving this problem under different household migration scenarios, we obtain the following characterization of optimal remittances:

Proposition D.2. *Conditional on the location and sector choices of Member 1 and Member 2, the optimal transfers under different household migration situations are as follows:*

1. *When Member 1 and Member 2 stay in the same place.*
   (a) *If $I_1 + I_2 \geq (\tilde{\lambda}_1 + \tilde{\lambda}_2)(I_1 + I_2 + I_3)$,*

$$T_1^* = (1 - \tilde{\lambda}_1)I_1 - \tilde{\lambda}_1 I_2 - \tilde{\lambda}_1 I_3; \quad T_2^* = (1 - \tilde{\lambda}_2)I_2 - \tilde{\lambda}_2 I_1 - \tilde{\lambda}_2 I_3;$$

   (b) *Else,*

$$T_1^* = \frac{\tilde{\lambda}_2 I_1 - \tilde{\lambda}_1 I_2}{\tilde{\lambda}_1 + \tilde{\lambda}_2}; \quad T_2^* = \frac{\tilde{\lambda}_1 I_2 - \tilde{\lambda}_2 I_1}{\tilde{\lambda}_1 + \tilde{\lambda}_2}$$

2. *When Member 2 migrates alone*
   (a) *If $I_1 + I_2 \geq (\tilde{\lambda}_1 + \tilde{\lambda}_2)(I_1 + I_2 + I_3))$ and $I_2 \geq \tilde{\lambda}_2(I_1 + I_2 + I_3)$,*

$$T_1^* = (1 - \tilde{\lambda}_1)I_1 - \tilde{\lambda}_1 I_2 - \tilde{\lambda}_1 I_3; \quad T_2^* = (1 - \tilde{\lambda}_2)I_2 - \tilde{\lambda}_2 I_1 - \tilde{\lambda}_2 I_3;$$

   (b) *If $I_2 \leq \tilde{\lambda}_2(I_1 + I_2 + I_3)$, while $I_1 \geq \frac{\tilde{\lambda}_1}{\tilde{\lambda}_1 + \tilde{\lambda}_3}(I_1 + I_3)$,*

$$T_1^* = \frac{\tilde{\lambda}_3 I_1 - \tilde{\lambda}_1 I_3}{\tilde{\lambda}_1 + \tilde{\lambda}_3}; \quad T_2^* = 0$$

   (c) *If $I_1 + I_2 \leq (\tilde{\lambda}_1 + \tilde{\lambda}_2)(I_1 + I_2 + I_3)$, and $I_2 \geq \frac{\tilde{\lambda}_2}{\tilde{\lambda}_1 + \tilde{\lambda}_2}(I_1 + I_2)$,*

$$T_1^* = \frac{\tilde{\lambda}_2 I_1 - \tilde{\lambda}_1 I_2}{\tilde{\lambda}_1 + \tilde{\lambda}_2}; \quad T_2^* = \frac{\tilde{\lambda}_1 I_2 - \tilde{\lambda}_2 I_1}{\tilde{\lambda}_1 + \tilde{\lambda}_2}$$

   (d) *If $I_1 \leq \frac{\tilde{\lambda}_1}{\tilde{\lambda}_1 + \tilde{\lambda}_3}(I_1 + I_3)$ and $I_2 \leq \frac{\tilde{\lambda}_2}{\tilde{\lambda}_1 + \tilde{\lambda}_2}(I_1 + I_2)$*

$$T_1^* = 0; \quad T_2^* = 0.$$

Note that $\tilde{\lambda}_1, \tilde{\lambda}_2, \tilde{\lambda}_3$ here are the adjusted utility weights for Member 1, Member 2 and Member

3, respectively. Let i denotes the type of family members, then for $i \in \{1, 2, 3\}$,

$$\tilde{\lambda}_i = \frac{\lambda_i \left(\frac{\lambda_i}{P_i}\right)^{\frac{\rho}{1-\rho}}}{\sum_{k=1}^{3} \lambda_k \left(\frac{\lambda_k}{P_k}\right)^{\frac{\rho}{1-\rho}}}.$$

Therefore, given the adjusted utility weights of family members, the pattern of optimal intra-household transfers here is the same as that in the baseline model with Stone-Geary preference. The proof of Proposition D.2 is similar to that of Proposition 1 in Online Appendix B.2, and we skip the detailed proof here.

Calibration The calibration procedure is the same as that of the baseline model in our main text, except for the calibration of PIGL preference parameters. Specifically, following Boppart (2014), we set the strength of the income effect ρ and the price effect χ in the consumer expenditure shares to 0.22 and 0.41, respectively. We set η to 0.41, and thus the term $\frac{\eta}{\chi}$ in the indirect utility function (see equation (D.13)) equals to 1, same as in Eckert and Peters (2022). The long-run asymptotic expenditure share on agriculture goods ϕ is set to 0, which is in line with Hao et al. (2020) and close to the value 0.01 in Eckert and Peters (2022). Finally, according to nationwide expenditure shares sourced from the China Statistical Yearbooks, we set the share of services goods consumption in total non-agriculture consumption α as 0.64. With this PIGL preference, the calibrated utility weights of three household members are 0.41, 0.41 and 0.18, respectively. The iceberg separation cost equals 10.70. All these values are quantitatively similar to those in our baseline model.

We then repeat the main counterfactual experiment of banning migrants' remittances. In this case, migrants cannot send remittances to support family members left behind. Given this restriction, the optimal transfer between household members will change once one or two of them become migrants. In detail, in the scenario with Member 2 migrating and Member 1 staying in the hometown, the transfer from Member 2 is 0, i.e., $T_2^* = 0$, and the optimal transfers between Member 1 and Member 3 change to:[28]

$$\begin{aligned} T_1^* &= \frac{\tilde{\lambda}_3 I_1 - \tilde{\lambda}_1 I_3}{\tilde{\lambda}_1 + \tilde{\lambda}_3}, && \text{if } I_1 \geq \frac{\tilde{\lambda}_1}{\tilde{\lambda}_1 + \tilde{\lambda}_3}(I_1 + I_3); \\ T_1^* &= 0, && \text{if } I_1 < \frac{\tilde{\lambda}_1}{\tilde{\lambda}_1 + \tilde{\lambda}_3}(I_1 + I_3). \end{aligned}$$

When Member 1 and Member 2 migrate together, even though they cannot send remittance back, transfers between these two members are allowed. Thus, the optimal transfers under this

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[28] The proof of optimal transfers here is similar to the proof in the baseline model with Stone-Geary preference, as in Online Appendix B.4.

scenario change to

$$T_1^* = \frac{\tilde{\lambda}_2 I_1 - \tilde{\lambda}_1 I_2}{\tilde{\lambda}_1 + \tilde{\lambda}_2}, \quad T_2^* = \frac{\tilde{\lambda}_1 I_2 - \tilde{\lambda}_2 I_1}{\tilde{\lambda}_1 + \tilde{\lambda}_2}.$$

Table D.6 reports the impacts of banning remittances on structural change. Overall, banning remittances increases the employment share in agriculture while decreases the employment shares in manufacturing and services. This reallocation effect is even stronger in the receiver region. Table D.7 reports the impacts of banning remittances on welfare and inequality. Same as in the baseline case, we find that banning remittances induces a decline in real income per capita for the whole economy and enlarges regional inequality. Hence, our main findings are qualitatively robust to the alternative PIGL preference.

Note that unlike the weighted geometric average in the benchmark model with Stone-Geary preference, we express the indirect household utility here as the weighted sum of each member's utility. In this case, for example, the marginal household utility from Member 2's one extra dollar consumption is independent of the other two members' consumption levels. Even though banning remittance interrupts the optimal income reallocation within the household, the migrant member can easily offset this loss through a higher-paid job. Therefore, compared to the benchmark analysis, the impact of banning remittance under PIGL preference is smaller.

Table D.6: The Impact of Banning Remittances on Sectoral Employment Shares: PIGL Preference

	Baseline: With Remittances	Counterfactual: Banning Remittances	Change
A. Overall			
Agriculture	42.1	42.3	0.2
Manufacturing	27.3	27.2	-0.0
Services	30.6	30.4	-0.1
B. Receiver Region			
Agriculture	58.4	58.7	0.3
Manufacturing	18.4	18.4	-0.0
Services	23.2	22.9	-0.3
C. Remitter Region			
Agriculture	23.2	23.2	0.1
Manufacturing	37.6	37.5	-0.0
Services	39.2	39.2	-0.0

Notes: This table reports the impacts of banning remittances on sectoral employment shares under PIGL preference. Columns 2 and 3 report the employment share (%) in the benchmark with remittances and in the counterfactual banning remittances, respectively. Column 4 is the corresponding percentage point change. The change of three sectors may not sum to 0 due to rounding.

Table D.7: The Impacts of Banning Remittance on Welfare and Inequality: PIGL Preference

	(1) All Cities	(2) Receiver Cities	(3) Remitter Cities
Panel A: Population-weighted Aggregate Variables			
△% Price	-0.04	-0.6	0.7
△% Nominal Income	-0.3	-4.2	3.4
△% Real Income	-0.2	-3.6	2.7
△% Household Welfare	0.0	-0.4	0.1
Panel B: Income/Welfare Inequality			
Var(Log Real Income) : Benchmark	0.24	0.24	0.19
Var(Log Real Income) : Ban Remittance	0.44	0.46	0.33
△% Var(Log Real Income)	80.1	89.4	74.2
Var(Log Household Welfare): Benchmark	2.46	1.28	2.38
Var(Log Household Welfare): Ban Remittance	2.48	1.29	2.39
△% Var(Log Household Welfare)	0.5	0.7	0.4

Notes: This table reports the impacts of banning remittances on welfare and inequality under PIGL preference. Panel A reports the impacts of banning remittance on the population-weighted aggregate variables. Panel B reports the inequality measured by the variance of log real income per capita and household welfare under the benchmark and the counterfactual of banning remittances, and the change in inequality induced by banning remittances. △% denotes the percentage change.

D.2 Robustness to Alternative Trade Costs

Our calibration strategy of trade costs is similar to Fan (2019) but we find smaller trade costs. This could be because we use a different year as the baseline. It can also be caused by other differences in our model. We now borrow the coefficients of trade costs estimation from Fan (2019) to show that our main findings are robust to alternative trade costs setting. Table D.8 presents the detailed value of each parameter in Fan (2019). We generate the trade costs based on these parameters and then take these costs as given to recalibrate the remaining part following the same procedure described in Section 4.2.3.

Table D.9 reports the impacts of banning remittances on structural change. As we can see, banning remittance drives employment from manufacturing and services to the agriculture sector, and this pattern is more significant for the receiver region. This reallocation pattern is similar to our baseline case. Table D.10 reports the impacts of banning remittances on welfare and inequality. Consistent with the findings in the main text, the whole economy suffers from banning remittances, especially for receiver cities. Moreover, banning remittances exacerbates regional inequality, increasing the variance of log real income and log household welfare. The main takeaways from our benchmark analysis are robust to alternative trade cost setting.

Table D.8: Trade Costs Parameters from Fan (2019)

	Trade Costs
Panel A: Domestic trade costs parameters	
I_1(Different cities, same province)	0.57
I_2(Different provinces, same region)	1.21
I_3(Different regions)	1.51
I_4(Common provincial border)	-0.06
$I_1 \times Dist$	0.01
$I_2 \times Dist$	0.21
$I_3 \times Dist$	0.04
Panel B. International trade costs parameters	
Agriculture	0.99
Manufacturing	0.80

Notes: Panel A reports the parameters of domestic trade costs. $Dist$ is the distance between two cities. Panel B reports the international trade costs parameters for agriculture and manufacturing.

Table D.9: The Impact of Banning Remittances on Sectoral Employment Shares: Alternative Trade Cost Setting

	Baseline: With Remittances	Counterfactual: Banning Remittances	Change
A. Overall			
Agriculture	42.1	42.8	0.7
Manufacturing	27.3	27.0	-0.3
Services	30.6	30.2	-0.4
B. Receiver Region			
Agriculture	59.0	60.0	1.1
Manufacturing	18.0	17.6	-0.4
Services	23.1	22.4	-0.7
C. Remitter Region			
Agriculture	24.1	24.4	0.3
Manufacturing	37.2	37.0	-0.2
Services	38.7	38.6	-0.0

Notes: This table reports the impacts of banning remittances on sectoral employment shares under alternative trade costs. Columns 2 and 3 report the employment share (%) in the benchmark with remittances and in the counterfactual banning remittances, respectively. Column 4 is the corresponding percentage point change. The change of three sectors may not sum to 0 due to rounding.

Table D.10: The Impacts of Banning Remittances on Welfare and Inequality: Alternative Trade Cost Setting

	(1) All Cities	(2) Receiver Cities	(3) Remitter Cities
Panel A: Population-weighted Aggregate Variables			
△% Price	-0.05	-0.2	0.1
△% Nominal Income	-0.9	-4.5	2.8
△% Real Income	-0.9	-4.3	2.7
△% Household Welfare	-0.3	-3.1	0.0
Panel B: Income/Welfare Inequality			
Var(Log Real Income) : Benchmark	0.13	0.13	0.10
Var(Log Real Income) : Ban Remittance	0.24	0.26	0.18
△% Var(Log Real Income)	88.4	100.3	75.3
Var(Log Household Welfare): Benchmark	1.92	0.86	1.98
Var(Log Household Welfare): Ban Remittance	1.97	0.89	2.02
△% Var(Log Household Welfare)	2.5	3.6	1.7

Notes: This table reports the impacts of banning remittances on welfare and inequality under alternative trade cost setting. Panel A reports the impacts of banning remittance on the population-weighted aggregate variables. Panel B reports the inequality measured by the variance of log real income per capita and household welfare under the benchmark and the counterfactual of banning remittances, and the change in inequality induced by banning remittance. △% denotes the percentage change.