Essays on Macroeconomic Analysis of Geographical Reallocation

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Abstract
This dissertation consists of two essays that study the determinants of geographical reallocation and their macroeconomic implications. In the first chapter (co-authored with Y. Fatih Karahan), we study the role of the aging population in the long-run decline of interstate migration in the United States. We argue that, in addition to a direct compositional effect on migration, the aging population has an indirect general equilibrium effect through the labor market. There is a positive composition externality of high-moving-cost workers on the local labor market: An increase in the fraction of high-moving-cost workers increases the local job-finding rate and reduces the migration rate of all workers. We label this effect as “migration spillovers.” Our quantitative analysis suggests that population aging decreases the annual interstate migration rate by 0.9 percentage points, which accounts for 59 percent of the observed decline. Of this 0.9 percentage points, 78 percent is attributable to the indirect general equilibrium effect of the aging population and only 22 percent is due to the direct effect.

In the second chapter (co-authored with Y. Fatih Karahan), we construct an equilibrium model of multiple locations with frictional housing and labor markets to study the effect of the housing bust on labor reallocation. The minimum down payment requirement makes it harder for homeowners to trade houses when house prices decrease. Consequently, the housing bust reduces migration and increases the unemployment dispersion. The model accounts for 90 percent of the increase in dispersion of unemployment and the entire decline in net migration. However, the effect on aggregate unemployment is moderate: absent the housing bust, aggregate unemployment would have been 0.5 percentage points lower.

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ESSAYS ON MACROECONOMIC ANALYSIS OF GEOGRAPHICAL REALLOCATION

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Suryun Rhee
To my beloved family, teachers, and friends.
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ABSTRACT

ESSAYS ON MACROECONOMIC ANALYSIS OF GEOGRAPHICAL REALLOCATION

Suryun Rhee
Dirk Krueger

This dissertation consists of two essays that study the determinants of geographical reallocation and their macroeconomic implications. In the first chapter (co-authored with Y. Fatih Karahan), we study the role of the aging population in the long-run decline of interstate migration in the United States. We argue that, in addition to a direct compositional effect on migration, the aging population has an indirect general equilibrium effect through the labor market. There is a positive composition externality of high-moving-cost workers on the local labor market: An increase in the fraction of high-moving-cost workers increases the local job-finding rate and reduces the migration rate of all workers. We label this effect as “migration spillovers.” Our quantitative analysis suggests that population aging decreases the annual interstate migration rate by 0.9 percentage points, which accounts for 59 percent of the observed decline. Of this 0.9 percentage points, 78 percent is attributable to the indirect general equilibrium effect of the aging population and only 22 percent is due to the direct effect.

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Chapter I

Population Aging, Migration Spillovers, and the Decline in Interstate Migration

1 Introduction

The rate of interstate migration in the United States has declined steadily from 3 percent in the mid-1980s to less than 1.5 percent in 2010. Had the rate of interstate migration stayed constant at its 1980 level, an additional 3.6 million workers per year would have changed their residential states in 2010. A large fraction of interstate migrants report having moved for a new job, for a job search, or for other job-related reasons. Given the importance of interstate migration for individual labor market outcomes, the decline in migration raises the concern that it might adversely affect the labor market. To draw conclusions about the labor market consequences of lower labor mobility, this paper studies its causes.

Specifically, we study the effect of the aging population on the decline in interstate migration. Population aging is a natural candidate for explaining the decline in migration, because migration rates decrease sharply over the life cycle. The migration rate of workers

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1This chapter is co-authored with Y. Fatih Karahan. The views expressed in this paper are those of the authors and do not necessarily reflect the position of the Federal Reserve Bank of New York or the Federal Reserve System.

2For example, on average, 50 percent of all interstate moves during the 2000s were job related (March CPS; authors’ calculations).

3Several recent papers study the effect of migration on individual labor market outcomes. Kennan and Walker (2011) find that interstate migration decisions are influenced to a substantial extent by income prospects. Gemici (2011) documents that wages of single women increase upon a move, whereas these of married women decrease.
below age 40 is around two times higher than that of workers older than 40.\textsuperscript{4} The age composition of the U.S. population has changed substantially over the period in which declining migration rates occurred. The share of individuals above age 40 in the working-age population increased from 62 percent in the 1980s to 75 percent in 2010.

However, as we show in section 2 in an accounting exercise, the direct effect of the aging population can account for only 20 percent of the decline. Both Kaplan and Schulhofer-Wohl (2013) and Molloy et al. (2013) evaluate the role of changes in demographics (for example, age, education, and household structure) and find that the direct effect of compositional changes in the population is too small to explain much of the decline. Most of the decline is accounted for by a declining trend common across all groups. These empirical observations have led researchers to rule out population aging as a quantitatively viable explanation and look for common factors affecting the migration decisions of everyone in the economy.\textsuperscript{5} Such logic, however, ignores the possibility that compositional changes may have an indirect general equilibrium effect on migration through the labor market. In this paper, we show, and empirically support, that, in addition to the direct compositional effect on migration, an increase in the share of old workers in the labor force reduces migration by inducing a lower equilibrium migration rate for \textit{all} workers (\textit{migration spillovers}).

To provide an empirical underpinning to our study of indirect effects, we start by analyzing the cross-state variation in the age composition of population and migration rates. We find that an increase in the share of “old” workers is associated with a lower mobility rate for workers at \textit{all} ages. One possible (and simple) explanation for this finding is that old

\textsuperscript{4}March CPS; authors’ calculation.  
\textsuperscript{5}Kaplan and Schulhofer-Wohl (2013) argue that the development of information technology and the decrease in the geographic specificity of occupations are responsible for lower migration rates. Molloy et al. (2013) propose a decline in labor turnover as a possible explanation.
workers sort into locations with a less dynamic labor market. If this is the case, both young and old workers residing in those states would be less likely to move. However, controlling for the possible endogeneity of the age structure in a state by instrumenting it with lagged birth rates, we find even larger elasticities. Our preferred specification suggests that workers between the ages of 25 and 40 are 28 percent less likely to move if they live in a state with a ten percent larger share of old workers. The same figure for those workers older than 40 is almost 60 percent! These results point to massive indirect effects of changes in the age structure of the labor force. To properly account for these effects, we need to understand the economic forces at play. The rest of the paper is dedicated to this task.

To that end, we analyze a simple economy consisting of two locations. Each location is populated by two types of workers whose moving costs differ. Workers can look for jobs in both locations. Low-moving-cost workers search for jobs in all locations, whereas high-moving-cost workers search only in their current location. Similarly, firms can create jobs for local residents or for out-of-towners. Workers can observe local jobs as well as jobs advertised for out-of-towners by the firms in the other location. An important outcome is that high-moving-cost workers are more attractive to firms, because their lower outside option allows firms to hire them at lower wages.

Our main theoretical result is that there is a positive composition externality of high-moving-cost workers on the local labor market: An increase in the share of high-moving-cost workers causes firms to create more jobs for local residents, thereby increasing the local job finding rate and decreasing the migration rate of all workers. This result is intuitive. When the share of high-moving-cost workers increases in the economy, jobs for local residents are more likely to be taken by high-moving-cost workers. In contrast, jobs created for out-of-
towners are always taken by workers with low moving costs. Thus, firms find it relatively more profitable to create jobs for local workers and less profitable to create jobs for out-of-towners. Consequently, local jobs become more abundant. This increase in the local job-finding rate lowers the equilibrium migration rate for all workers. We label this effect as “migration spillovers.”

We then ask if this theory can quantitatively explain the cross-sectional relationship between population flows and the age structure. To that end, we enrich the simple model and calibrate it by targeting several labor market and migration-related moments during the 1980s. The model reproduces remarkably well the cross-sectional elasticity of migration with respect to age composition. The mechanism at play is that local job finding rate rises in the state experiencing an increase in the old population share, so that the migration incentives of all workers decline, resulting in lower mobility for workers in that state, independent of age. We provide direct evidence for the mechanism, in a much similar fashion, by exploiting cross-state heterogeneity in the age structure. Here, we document that local job finding rates increase in states that age more. The estimated elasticity is quantitatively consistent with that in the model.

Given the quantitative success of the model and the empirical evidence in favor of the mechanism, we turn to the time series of migration. Keeping all parameters of the model constant, we only change the population composition to mimic the U.S. population in 2010. The calibrated model generates a decline in migration of 0.9 percentage points. This decline corresponds to around two-thirds of the decline in the data. We find that, of this 0.9 percentage point decline, almost 80 percent is due to migration spillovers and just 20 percent is due to the direct effect of compositional change. Consistent with the data, our model
generates sizable declines in migration rates for workers at all ages through the indirect effect. Thus, our results suggest that accounting for the migration spillovers is important in evaluating the effect of compositional changes in the population.

Finally, we use our model to assess the implications of lower geographical mobility for aggregate unemployment. Our explanation for the long-run decline in migration suggests that the labor market concern may be misplaced. We find that the large decline in migration causes only a slight increase in aggregate unemployment. The upward pressure on unemployment caused by the limited search opportunities of older workers is largely offset by the general equilibrium effect that increases the job-finding rate of all workers.

Our paper is related to several strands of the literature on migration and labor market. In their seminal 1992 paper, Blanchard and Katz (1992) find evidence that population flows are an important adjustment mechanism for recovery following adverse local shocks. In response to their work, there is an extensive empirical and theoretical literature which tries to understand worker flows and their interactions with regional labor markets. One such paper, Coen-Pirani (2010), studies cross-sectional properties of gross and net worker flows across states. We differ from Coen-Pirani (2010) in that our emphasis is on the time series of gross flows. Recent literature also studies the interactions between the housing market and gross and net worker flows.6

On the theoretical front, we build on the island framework in Lucas and Prescott (1974) and model the local labor market with search frictions as in ?. Alvarez and Shimer (2011) develops a tractable island model to study rest and search unemployment. Similar to ours,

Lkhagvasuren (2011) and Carrillo-Tueda and Visschers (2013) use an island model with search frictions.\textsuperscript{7}

The rest of the paper is organized as follows. Section 2 documents the stylized facts on the decline in interstate migration and presents the cross-state analysis. Section 3 describes a simple model and presents the main proposition regarding the spillover effect. Section 4 presents the quantitative model, our calibration, and the results. Finally, section 5 concludes.

2 Empirical Analysis

We start this section by describing the various data sources used in the analysis. We then document the long-run decline in interstate migration in the United States and explore its various components. This is followed by an investigation of the effects of population aging using cross-state variation.

2.1 Data

Migration rates are computed using micro data from the Annual Social and Economic Supplement to the Current Population Survey (March CPS). In order to focus on migration that is not motivated by changes in schooling (for example, college attendance and graduation) or retirement, we restrict the sample to nonmilitary/civilian individuals who are between the ages of 25 and 60 at the time of the survey. March CPS is obtained from the Integrated Public Use Micro data Series (King et al. (2010)).\textsuperscript{8} After 1996, we exclude observations with imputed migration data to avoid complications arising due to changes in CPS imputation.

\textsuperscript{7}Lutgen and Van der Linden (2013) study the efficiency implications of job search opportunities in multiple locations. Similar to Lutgen and Van der Linden (2013), in our paper the worker’s job search is not limited to his or her current location.

\textsuperscript{8}The data can be obtained on \url{https://cps.ipums.org/cps/}.
procedures.\footnote{See Kaplan and Schulhofer-Wohl (2012) for a detailed explanation.}

We obtain annual population estimates for various age groups in each state from the Census.\footnote{All population files are downloaded from \url{http://www.census.gov/popest/data/historical/index.html}. More detailed information about population estimates is provided in the Appendix.} Similar estimates can also be obtained using the CPS sample that is used for the computation of migration rates. We use the estimates provided by the Census; however we have verified the robustness of our results.

Following Shimer (2001), we obtain exogenous variation in age-composition by instrumenting with lagged birth rates. These are measured in births per thousand of residents and are available in the various Statistical Abstracts of the United States. We are grateful to Rob Shimer for providing us with his data. As explained in Shimer (2001), data are unavailable for Hawaii and Alaska prior to 1960. We drop these states from the analysis.\footnote{The omission does not affect the results in any meaningful way.}

To validate the mechanism proposed in this paper, we construct a measure of state-specific job finding rates. More specifically, we want to obtain the fraction of the unemployed in a state that find a job in the same state in a period of time. This requires the use of a proper panel of workers. We therefore turn to the Survey of Income and Program Participation (SIPP). We provide more details about the SIPP as it is less commonly used in the migration literature.\footnote{Two exceptions we are aware of are Aaronson and Davis (2011) and Guler and Taskin (2012).} SIPP is a large representative sample of households interviewed every four months (a “wave”) for two to four years. The first panel begins in 1984, and a new cohort is added around the time when the previous cohort exits. We have around 4.2 million individual-wave observations between 1984 and 2012. Migration information can be constructed in all but the first wave of each panel. Some summary statistics are presented in...
Appendix C. As explained in Aaronson and Davis (2011), SIPP is useful to study migration behavior because it tracks households when they move to different addresses, and because it contains various demographic information.\(^\text{13}\)

### 2.2 Aggregate facts

The blue line in figure 1 plots the evolution of interstate gross migration rates from the March CPS, and the red solid line is the long-run trend of the same. Figure 1 points to a long-run decline starting in the mid-1980s with little business cycle variation. The decline is substantial: Interstate migration rate in 2010 is only 50 percent of the same figure in 1980s.

Is the decline concentrated in certain states? One conjecture is that interstate migration might have slowed down because of lower net flows. For example, the 1980s were a time of relatively large flows out of the so-called “Rust Belt” area. Net flows across states are an order of magnitude smaller than gross flows, as we also show in figure 1; so the large fall in gross migration is unlikely to be explained by changes in net flows. Figure 2 show the spatial nature of the fall in migration rates. While the magnitude of the fall is different across states, an important variation to test various theories, migration has fallen virtually in all states. This paper will explain a nontrivial portion of the decline as well as its spatial heterogeneity.

To better understand the nature of the decline in migration, figure 3 shows the fraction of the working-age population that moved across states for different reasons. Of the variety of reasons to move,\(^\text{14}\) moves motivated by job-related factors have declined sharply, whereas

\(^{13}\)Data can be downloaded from [http://thedataweb.rm.census.gov/ftp/sipp_ftp.html](http://thedataweb.rm.census.gov/ftp/sipp_ftp.html).

\(^{14}\)These reasons include job-related factors (e.g., for a new job, job-transfer, job search, easier commute, etc.), family-related factors (e.g., changes in marital status, to establish one’s own household, etc.), housing-related factors (e.g., to own, better housing, better neighborhood, etc.), and other reasons (e.g., foreclosure,
other moves have changed unnoticeably. This observation rules out theories based on increases in direct moving costs, as such increases would cause lower migration rates in all categories.

One natural candidate for explaining the decline in migration is the aging of the population over the last 30 years. As shown in figure 4, the U.S. population has aged substantially: The fraction of working-age population older than 40 has increased from 62 percent in the 1980s to 75 percent in 2010. It is well known that there are large migration differences across age groups. To illustrate this, figure 5 plots the interstate migration rate over the working life. People between the ages of 25 and 29 are almost four times more likely to move across states than those aged 50 to 54.

The effect of the aging population on interstate migration can be categorized into two categories. The first is a direct effect. Mechanically, the aggregate migration rate is a weighted average of age-specific migration rates. Thus, demographic changes alter the weights, and the migration rate, without affecting the “within-group” migration rates. To evaluate the direct effect of compositional change, we conduct an accounting exercise. At any point in time, the migration rate can be written as a weighted sum of group-specific migration rates:

\[ m_t = \sum_i s_{i,t} \times m_{i,t}, \]

where \( s_{i,t} \) and \( m_{i,t} \) are group-specific shares and migration rates at time \( t \), respectively.

Fixing the migration rate of every age group to its level in 1980, we construct a counterfactual natural disaster, etc.).
migration rate by changing only the shares of age groups:

\[ \hat{m}_t = \sum_i s_{i,t} \times \bar{m}_{i,t}. \]

Under this formulation, any change in the migration rate, \( \Delta \hat{m} \), is driven by the change in the share of each age group; that is,

\[ \Delta \hat{m} = \sum_i \Delta s_{i,t} \times \bar{m}_{i,t}. \]

The red line in figure 6 plots the resulting counterfactual migration rates. The result suggests that the direct effect of the aging population accounts for 20% of the decline.

Based on this finding, we investigate how the life-cycle pattern of migration has evolved. Figure 7 plots the migration rates of different age groups. Interstate migration has declined for all ages. This common decline across ages accounts for most of the observed decline in interstate migration. Thus, to understand why migration has declined, we need to understand why migration has fallen for workers at all ages.

### 2.3 Cross-state Variation in Population Aging and Migration Rates

Second, changes in the age composition may have indirect effects on migration by changing the age-specific migration rates. The main empirical analysis for testing and measuring the indirect effect relies on cross-state differences in the age composition of the labor force, and the consequent variation in migration rates. The goal is to figure out what would happen to the mobility of a young and an old worker if she were to be transferred to a location with a higher share of older workers. To that end, we compute the aggregate and age-specific
outflow rates for each state. The sample size of the CPS is too small at the state level to yield reliable estimates of age-specific mobility. To have sufficient precision, we focus on two age groups: Individuals between the ages of 25 and 39 and those older than 40 and younger than 65. With a slight abuse of language, we refer to the first group as “young workers” and the second group as “old workers.”

**OLS Results** The main empirical specification looks at how the outflow rate in state $i$ and year $t$ depends on the share of the labor force older than 40, $share_{it}$.

$$\log \text{mobility}_{it} = \alpha_i + \beta_t + \gamma \log share_{it} + \epsilon_{it}. \tag{1}$$

Here, $\alpha_i$ and $\beta_t$ denote state and time fixed effects, respectively. $\epsilon_{it}$ captures other sources of variation. State fixed effects are needed to dispose of any unmeasured state level fixed factor that might simultaneously affect the age composition as well as the mobility in a state. Similarly, time fixed effects are needed to take out the effects of the various aggregate shocks that may have hit the U.S. economy during our sample period. We first estimate equation (1) with OLS and later instrument for the variation in the age-composition with lagged birth rates across states. To deal with the serial correlation in the residual, standard errors are clustered around state.

The left panel of table 1 reports the OLS results. Column 1 shows the results from estimating equation (1) using aggregate migration rate data from 1980 to 2010. The estimated elasticity of migration with respect to the share of “old” workers is -1.8. This coefficient is significantly different from zero at any commonly used confidence level. A ten-percent increase in the share of workers older than 40 is associated with an 18 percent decline in the
migration rate out of that location.

Clearly, there is a mechanical caveat with this estimate. Since older workers have a lower migration propensity, one would expect the migration rate to be lower in older states. The magnitude and significance of this coefficient could be entirely driven by the composition effect. More interesting results are presented in the second and third columns of panel A of table 1. An increase in the share of old workers in a state is correlated with a significant reduction in the migration rate of all workers, conditional on their age. Quantitatively, the elasticity is twice as large for workers older than 40 (-2.15) than the elasticity of younger workers (-1.77).

**IV Results** One possible explanation for these results is that old workers move to states with a less dynamic labor market, say with a lower separation rate, and thus do not need to move as much. As a result, both young and old workers residing in those states move less compared to identical workers in other states. Note that if a state has a less dynamic labor market throughout our sample, this would be captured by state fixed effects. A bias in the coefficient would arise if a state has a temporary change in its labor market that temporarily attracts more older workers. One way to control this issue is to include more controls. While we have established the robustness of our findings in table 1 to other controls, we pursue an alternative route here and use an instrument to establish causal inference.\(^{15}\)

Our instrumental variable strategy follows Shimer (2001) and exploit the variation in the age composition in a state induced by the birthrates in that state in the past. More specifically,

\(^{15}\)We have included state-wide measures of personal income, industrial composition, homeownership rate, college completion rate, and marriage rate to the specification in (1). The coefficient on age composition is always negative and significant for all age groups and is quantitatively similar, in a statistical sense, to those reported in table 1.
our instrument in state $i$ and year $t$ is defined as the sum of all birth rates in state $i$ from year $t-39$ to $t-25$. The instrument turns out to do a good job in inducing variation in the age composition. In the first stage, we regress the share of old workers on a full set of state and time dummies and the birth rate. This yields a coefficient of 0.40 and a standard error of 0.02. Birthrates explain about 21 percent of the residual variation in age composition, after accounting for fixed effects. Together with the fixed effects, the specification explains 96 percent of the variation.

Panel B of table 1 present the results of the IV regression. The resulting elasticities are strikingly larger than the OLS estimates: A 10 percent increase in a state’s share of old workers causes outflow rates in that state to go down by almost 38 percent. There is also a remarkable difference in the elasticity of young and old workers. A young worker would be 37 percent less likely to move if she were to live in a state with a ten percent larger share of old workers. The same figure for an old worker is 60 percent.\footnote{If old workers were moving to states with a less dynamic labor market, the IV estimates would have been substantially lower. The finding that IV results in larger elasticities is indicative of measurement error in the population estimates.}

The next question that we tackle in this paper is what explains these patterns? What is it that makes workers that live in states with an older population move less? Section 3 presents a mechanism through which compositional changes affect group-specific migration rates. This mechanism is an indirect general equilibrium effect that operates through a change in the labor market and lowers the equilibrium migration rate for all individuals (migration spillovers).
3 Theoretical Insights from a Simplified Model

To illustrate the indirect effect of compositional change through general equilibrium, we analyze an economy with infinite locations populated by two types of workers whose moving costs differ. The model combines the island framework in Lucas and Prescott (1974) and the local labor market with search frictions in ?.

3.1 Environment

Time is discrete. The economy consists of infinite locations (“islands”). Each location is populated by a continuum of infinitely lived, risk-neutral individuals who can be of two types. The first type, which we label “settlers,” faces very large moving costs, and thus they never move. Individuals of the second type, labeled “nomads,” do not face any moving costs and are perfectly mobile. Due to the cost of search, unemployed settlers search for jobs only within their current location, whereas unemployed nomads search for jobs in both locations. A fraction $\phi$ of the population are settlers. The goal of this section is to show that an increase in $\phi$ may result in a lower migration rate for nomads through a general equilibrium effect.

Firms advertise for vacant positions by paying a fixed cost, $\kappa$, to attract workers. There are two ways to advertise a position. One such way is through “local” channels; e.g. via local newspapers, in local job fairs, by posting the ad on walls, etc. Jobs advertised this way can only be seen by local residents. We label this as the “local” market. Another option for firms is to reach out to more people globally by, for instance, using online job boards. We label this as the “global” market and the jobs in this market are common information to all
the unemployed. Thus, there are two job markets for each island; one local and one global.

All labor markets are subject to search frictions. Matches are determined by the constant-
returns-to-scale (CRS) matching function \( m(v, u) \), where \( v \) and \( u \) indicate the number of
job postings and the number of unemployed workers in a labor market, respectively. Job-
and worker-finding probabilities for workers and firms are determined by the relevant mar-
ket tightness. Let \( \theta^l_i \) and \( \theta^g_i \) denote the market tightnesses in location \( i \) in the local and
global markets, respectively. \( q(\theta) \) is the worker-finding rate for a firm, whereas \( p(\theta) \) is the
job-finding probability for an unemployed worker.\(^{17} \) Locations are the same in terms of
fundamentals. Therefore we simplify the notation and drop the location superscript \( i \).

3.2 The Problem of Workers and Firms

We start with workers’ problem. A nomad sends out The following equations show the value
of being unemployed for both types of workers. A superscript of \( s \) denotes a settler, whereas
\( n \) refers to a nomad:

\[
U^s = b + \beta p_l \left[ W^s(w^s) - U^s \right]
\]

\[
U^n = b + p_l \left[ W^n(w^n_l) - U^n \right] + p_g \left[ W^n(w^n_g) - U^n \right]
\]

Once employed, the match dissolves with probability \( \delta \) regardless of the type of worker. The
value of employment for type \( i \) worker is given by the following equations:

\[
rW^i(w) = w + \delta \left[ U^i - W^i(w) \right].
\]

\(^{17} q(\cdot) \) is decreasing and \( p(\cdot) \) is increasing with respect to \( \theta \): \( q'(\theta) < 0 \) and \( p'(\theta) > 0 \).
Firms matched with a worker collect $y - w$ until the match is dissolved. Thus, the value of a matched firm is given by

$$rJ(w) = y - w - \delta J(w).$$

### 3.3 Wage Determination

Wages are determined by Nash bargaining between a firm and a worker, with $\eta$ denoting worker’s bargaining power. The following equations define the wage-determination problem in a worker-firm pair:

$$w^s = \arg\max \left\{ W^s(w) - U^s \right\} J(w)^{1-\eta}$$

$$w^n_l = \arg\max \left\{ W^n(w) - U^n \right\} J(w)^{1-\eta}$$

$$w^n_g = \arg\max \left\{ W^n(w) - U^n \right\} J(w)^{1-\eta}$$

Note that the wage of a nomad is independent of the market in which she meets the firm. Thus, we define $w^n$ as $w^n \equiv w^n_l = w^n_g$.

### 3.4 Steady-State Equilibrium

We assume free entry of firms. This ensures that, in equilibrium, the value of creating a vacancy will be zero in each market. The most important distinction between these two markets is in the types of workers that show up. Settlers only look for jobs that are in their location and show up in the global market only for jobs in their own location. Therefore, their share in the local market is higher relative to that in the global market. Equations (2)
and (3) describe the free-entry conditions in the distant and local markets, respectively:

\[
\kappa = q_g \left\{ \frac{u^s}{u^s + 2u^n} J^s + \frac{2u^n}{u^s + 2u^n} J^n \right\} \quad (2)
\]

\[
\kappa = q_l \left\{ \frac{u^s}{u^s + u^n} J^s + \frac{u^n}{u^s + u^n} J^n \right\} . \quad (3)
\]

where \( u^j \) is the steady-state measure of unemployed individuals of type \( j \). Both conditions equate the cost of posting a vacancy to the expected value of creating a vacancy. As we noted above, both types of workers show up in both markets. However, due to selection, settlers are more heavily represented in the local market relative to the global market. Thus, the expected value of a vacancy is a weighted average of the profits of employing each type, where the weights are given by the share of each type in the unemployment pool.

As shown in Diamond (1982) and Mortensen (1982), Nash bargaining splits the surplus of a match between the worker and the firm according to their bargaining power. In particular, the worker gets \( \eta \) share of the surplus, and the firm gets the remainder. Using the value functions of workers and firms, we show that the surplus generated by a firm and a settler is given by

\[
S^s(\theta_l, \theta_g) = \frac{y - b}{r + \delta + \eta (p_l + p_g)} . \quad (4)
\]

The surplus of a match between a firm and a nomad is (independent of location and) given by

\[
S^n(\theta_l, \theta_g) = \frac{y - b}{r + \delta + \eta (p_l + 2p_g)} . \quad (5)
\]

The effective discount factor in the match with a settler is \( r + \delta + \eta (p_l + p_g) \). Note that the effective discount factor for a nomad differs from that of the settler by \( \eta p_g \). This difference
is due to the additional job search opportunity of nomads, which arises from the option of searching in the distant labor market. Consequently, the surplus of a match with a settler is larger than that with a nomad: $S^s(\theta_l, \theta_g) > S^n(\theta_l, \theta_g)$ for all positive $\theta_l$ and $\theta_g$. Using the Nash bargaining solution that $J^i = (1 - \eta) S^i$, we now rewrite the free-entry conditions in equations (2) and (3) as functions of match surplus functions.

\begin{align*}
\kappa &= (1 - \eta) q_g \left\{ \frac{u^s}{u^s + 2u^n} S^s + \frac{2u^n}{u^s + 2u^n} S^n \right\} \\
\kappa &= (1 - \eta) q_l \left\{ \frac{u^s}{u^s + u^n} S^s + \frac{u^n}{u^s + u^n} S^n \right\}.
\end{align*}

**Remark 1.** *(Equilibrium Wages)* In equilibrium, the wage of settlers is lower than that of nomads:

\[ w^s < w^n. \]

The result is straightforward given the relative sizes of the surpluses of these matches. The details of the derivation can be found in appendix B.1. The fact that firms pay lower wages to settlers than to nomads indicates that the job creation of firms may change when the composition of the population changes. In the next proposition, we study the effect of a higher share of settlers on the equilibrium tightnesses of the different labor markets.

**Proposition 1.** *(Share of immobile workers and labor market tightnesses)* If the elasticity of the worker-finding rate with respect to the market tightness is high enough compared to the bargaining share of workers $\eta$, 
1. The local labor market tightness increases with the measure of immobile workers:

\[ \frac{d\theta_l}{d\phi} > 0. \]

2. The distant labor market tightness is inversely related to the measure of immobile workers:

\[ \frac{d\theta_d}{d\phi} < 0. \]

The details of the proof of the proposition can be found in appendix B. As we have noted before, remark 1 shows that firms make a higher profit from a match with a settler. Fixing market tightnesses, the share of settlers among the unemployed pool, \( \frac{u_s}{u_s + u_n} \), increases with \( \phi \), thereby increasing the expected profit from a vacancy in the local market (see equation (37)). In equilibrium, \( \theta_l \) must become higher for the free-entry condition in equation (37) to hold. The increase in local opportunities in turn reduces the surplus of a match with a nomad, \( S^n_d \). As a result, firms expect less profit in the distant labor market. For the free-entry condition in this market to hold, \( \theta_d \) must decrease.

We now turn to the implications of proposition 1 for the equilibrium migration rate and unemployment. Recall that in our model, only the nomads move in the event of an unsuccessful local search and a successful distant job search. Thus, their migration rate depends crucially on the local and distant job-finding rates. The next corollary shows that the migration rate of nomads is decreasing in the share of settlers, \( \phi \).

**Corollary 2.** (Share of settlers and the equilibrium migration rate of nomads) As the mea-
sure of settlers increases, the migration rate (mr) of nomads decreases:

\[
\frac{d\text{mr}}{d\phi} < 0.
\]

Proposition 1 implies that an increase in the share of settlers increases the local job-finding probability, but decreases the job finding rate in the distant market. The migration rate of an unemployed nomad is given by \((1 - p(\theta_l))p(\theta_d)\) and is clearly decreasing in \(\phi\). Moreover, the overall migration rate of nomads, measured as \(\frac{(1-p(\theta_l))p(\theta_d)u^n}{0.5-\phi}\), also decreases with \(\phi\). We label this general equilibrium effect migration spillovers.

Now, we use our model to study the implication of changes in population composition for equilibrium unemployment.

**Corollary 3.** (Share of settlers and the equilibrium aggregate unemployment rate)

1. The conditional unemployment rates \((ur^j)\) decrease for all types:

\[
\frac{dur^s}{d\phi} < 0 \quad \text{and} \quad \frac{dur^n}{d\phi} < 0.
\]

2. The effect on the aggregate unemployment rate is ambiguous; and it is positive if the compositional effect (larger share of settlers) is greater than the general equilibrium effect.

In this model, there are two effects in the increase of share of settlers, \(\phi\), on unemployment. The first is a general equilibrium effect. This effect arises because firms, in response to an increase in \(\phi\), post more vacancies in the local labor market and fewer vacancies in the distant market. Meanwhile, there is also a compositional effect at work that is captured
by the first term: an increase in settlers with a higher unemployment rate because of their limited job search capabilities puts an upward pressure on aggregate unemployment. To sum up, the effect on aggregate unemployment is ambiguous and depends on the relative sizes of the two effects.

In this section, we have developed a simple model of migration and used it to demonstrate how the equilibrium migration rate of perfectly mobile nomads is affected by changes in the population composition. The key to this result is that in the local market, there is no market segmentation by type. To illustrate the role of this labor market structure in generating the results, we now turn to an alternative search process and introduce a market segmentation parameter, \( \rho \). With probability \( 1 - \rho \), we assume that nomads search along with settlers in the local labor market. With probability \( \rho \), however, nomads participate in a segregated local labor market. If \( \rho = 0 \), this environment is identical to the model we already presented. As \( \rho \) approaches 1, the local market becomes completely segregated.

All the equations pertaining to this model and the related derivations are presented in appendix B.6. Figure 8 shows that if the local labor market is perfectly segregated by type, the change in population composition does not affect the migration rate of nomads. Thus, there is no migration spillover. The extent of the migration spillover is measured by the slope of the line, and it is decreasing in \( \rho \).

4 Quantifying the Importance of Migration Spillovers

In this section, we extend the model in section 3 and evaluate quantitatively the effect of an aging population on interstate migration. First, we allow for multiple types of workers with
finite moving costs. Each type corresponds to a specific age group in the data. Second, we introduce heterogeneity in the permanent preferences for locations. This results in variation in the age composition across locations. The rest of the quantitative model builds on the structure of the labor market presented in section 3.

4.1 Model

4.1.1 Environment

The economy consists of two locations, A and B, that are populated by \( N \) types of infinitely lived workers. Workers of various types differ in their moving costs and their permanent preference for A over B. Workers have preferences that are ordered according to

\[
\sum_{t=0}^{\infty} u_j(c_t, \epsilon_i),
\]

where \( i \) is the worker’s type, \( j \) denotes his location in period \( t \), \( c_t \) is his consumption, and \( \epsilon_i \) is his preference for A. We assume linear utility and express the utility function \( u \) as

\[
u_j(c, \epsilon) = \begin{cases} 
c + \epsilon & \text{if } j = A \\
c - \epsilon & \text{if } j = B. 
\end{cases}
\]

\( \epsilon \) is distributed according to a normal distribution with mean \( \mu_{\epsilon,i} \) and variance \( \sigma^2 \).

A worker can be employed or unemployed. At the beginning of the period, unemployed workers decide whether they want to move to the other location. After job destruction, shocks are realized and labor markets open. Firms post vacancies, and unemployed workers look for jobs. Job search consists of two stages. In the local job search stage, workers
apply for jobs in their own location. This is followed by a distant search, in which those workers that were unable to secure a local job decide whether to look for a job in the other location. Once all local and distant matches are formed, the migration stage opens. Finally, production is made, and wages are paid out. The following describes the timing of events within a period:

1. Unemployed workers migrate to their preferred location.

2. Separation shock hits existing matches with probability $\delta$.

3. The local labor market opens: unemployed workers look for local jobs.

4. The distant labor market opens: unemployed workers that could not find a local job decide whether to look for a job in the other location.

5. Workers who accept an offer from the other location pay the moving cost and move.

6. Production is made, and wages are paid.

Similar to the simple model, there are four different market tightnesses that govern job- and worker-finding probabilities for workers and firms, respectively. Let $\theta^j_l$ and $\theta^j_d$ denote the market tightnesses in the local and distant labor markets in location $j$.

4.1.2 Value Functions and Decision Rules

The following equations describe the value of employment and unemployment to workers residing in A and B:
\begin{align*}
W^A (w, \epsilon, \mu) &= w + \epsilon + \beta \left[ (1 - \delta) W^A (w, \epsilon, \mu) + \delta U^A (\epsilon, \mu) \right] \quad (8) \\
W^B (w, \epsilon, \mu) &= w - \epsilon + \beta \left[ (1 - \delta) W^B (w, \epsilon, \mu) + \delta U^B (\epsilon, \mu) \right] \\
U^A (\epsilon, \mu) &= b + \epsilon + \beta \left[ \max \left\{ \Sigma^A (\epsilon, \mu), \Sigma^B (\epsilon, \mu) - \mu \right\} \right] \\
U^B (\epsilon, \mu) &= b - \epsilon + \beta \left[ \max \left\{ \Sigma^A (\epsilon, \mu) - \mu, \Sigma^B (\epsilon, \mu) \right\} \right],
\end{align*}

where \( \Sigma^j \) is the value of being in location \( j \) at the beginning of the local job search stage. It is given by

\begin{align*}
\Sigma^j (\epsilon, \mu) &= p \left( \theta_j^l \right) W^j \left( w^j_l (\epsilon, \mu), \epsilon, \mu \right) + \left( 1 - p \left( \theta_j^l \right) \right) \Delta^j (\epsilon, \mu) \\
&= \Delta^j (\epsilon, \mu) + p \left( \theta_j^l \right) \left\{ W^j \left( w^j_l (\epsilon, \mu), \epsilon, \mu \right) - \Delta^j (\epsilon, \mu) \right\}.
\end{align*}

Here, \( w^j_l (\epsilon, \mu) \) is the equilibrium wage in the local labor market of \( j \) to a worker with preference \( \epsilon \) and moving costs \( \mu \), and \( \Delta^j \) represents the value of participating in the distant job search in the other location, \(-j\), while residing in location \( j \), and is given by

\begin{align*}
\Delta^j (\epsilon, \mu) &= \max \left\{ U^j (\epsilon, \mu), p \left( \theta_d^{-j} \right) \left( W^{-j} (w_d^{-j} (\epsilon, \mu), \epsilon, \mu) - \mu \right) + \left( 1 - p \left( \theta_d^{-j} \right) \right) U^j (\epsilon, \mu) \right\} \\
&= U^j (\epsilon, \mu) + \max \left\{ 0, p \left( \theta_d^{-j} \right) \left( W^{-j} (w_d^{-j} (\epsilon, \mu), \epsilon, \mu) - \mu - U^j (\epsilon, \mu) \right) \right\}.
\end{align*}

Here, \( w_d^{-j} (\epsilon, \mu) \) is the equilibrium wage in the distant labor market of \(-j\) to a worker with preference \( \epsilon \) and moving cost \( \mu \).
For firms, the value of employing a worker at a fixed wage $w$ is denoted by $J(w)$ and is given by

$$J(w) = y - w + \beta (1 - \delta) J(w).$$

(9)

It is easy to show that the migration behavior of all types of workers is characterized by cutoff rules. For each type, these rules are summarized by four cutoff preferences: $\epsilon_{A,l}(\mu), \epsilon_{B,l}(\mu), \epsilon_{A,d}(\mu),$ and $\epsilon_{B,d}(\mu).$ The cutoff $\epsilon_{A,l}$ governs the migration decision for a worker residing in $A$ at the beginning of the period. Workers with $\epsilon \geq \epsilon_{A,l}(\mu)$ decide to stay in $A$ and engage in a local job search there. Workers with $\epsilon < \epsilon_{A,l}(\mu)$ move to $B$ before a local job search begins. This cutoff is defined by the following equation:

$$\Sigma^A(\epsilon_{A,l}(\mu), \mu) = \Sigma^B(\epsilon_{A,l}(\mu), \mu) - \mu.$$  

(10)

Similarly, we define $\epsilon_{B,l}(\mu)$ as follows:

$$\Sigma^A(\epsilon_{B,l}(\mu), \mu) - \mu = \Sigma^B(\epsilon_{B,l}(\mu), \mu).$$

(11)

Workers residing in $B$ move to $A$ at the beginning of the period, only if their preference parameter $\epsilon$ is higher than $\epsilon_{B,l}(\mu)$.

$\epsilon_{A,d}(\mu)$ and $\epsilon_{B,d}(\mu)$ govern the cutoff preferences for participating in the distant labor

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18This cutoff property arises because the auxiliary value functions $\{\Sigma^j, U^j, W^j\}_{j \in \{A,B\}}$ are strictly monotonic with respect to $\epsilon$. 

25
market, and they are defined by the following equations:

\[
U^A(\epsilon_{A,d}(\mu), \mu) = W^B(w, \epsilon_{A,d}(\mu), \mu) - \mu
\]

(12)

\[
U^B(\epsilon_{B,d}(\mu), \mu) = W^A(w, \epsilon_{B,d}(\mu), \mu) - \mu.
\]

(13)

An individual living in A that could not find a local job decides to try his chance in the distant job market of B if and only if \( \epsilon < \epsilon_{A,d}(\mu) \). Similarly, residents of B that did not secure a job in B apply for positions in A if and only if \( \epsilon > \epsilon_{B,d}(\mu) \).

A consequence of having four cutoff values describing migration behavior in the model is that there are five possible categories of migration patterns:

1. A-lover: \( \epsilon_{A,d} \leq \epsilon \). A worker in this category always lives in A and does not look for a job in B.

2. Weak preference for A: \( \epsilon_{A,l} < \epsilon < \epsilon_{A,d} \) and \( \epsilon > \epsilon_{B,l} \). A worker in this category lives in A and moves to B only if he cannot find a job in A and finds a job in B. This worker moves back to A immediately upon losing the job in B.

3. Status quo: \( \epsilon_{A,l} < \epsilon < \epsilon_{A,d} \) and \( \epsilon_{B,d} < \epsilon < \epsilon_{B,l} \). A worker in this range prefers his current location and moves only if the local job search turns out to be unsuccessful and a distant offer comes along.

4. Weak preference for B: \( \epsilon_{B,d} < \epsilon < \epsilon_{B,l} \) and \( \epsilon < \epsilon_{B,l} \). Such a worker stays in B while unemployed and moves to A only in the event of a job offer from A. He returns to B immediately after the job in A is terminated.

5. B-lover: \( \epsilon < \epsilon_{B,d} \). A worker in this category always stays in B and never participates
in the distant labor market of A.

### 4.1.3 Wage Determination

We now describe the wage determination between a worker and a firm. Workers and firms meet in the local and distant labor markets. Upon meeting, they decide on the wage by engaging in Nash bargaining. For simplicity, we assume that firms offer a fixed-wage contract.\(^\text{19}\) The bargaining problem in the local labor market is given by

\[
W^j_l (w, \epsilon, \mu) = \arg \max \left[ W^j_l (w, \epsilon, \mu) - \Delta^j (w, \epsilon, \mu) \right]^{\eta} J (w)^{1-\eta}.
\]  

(14)

Note that the outside option of the worker in the local bargaining problem is \(\Delta^j\) and includes the option value of searching in the distant labor market. Similarly, the bargaining problem in the distant market is given by

\[
W^j_d (\epsilon, \mu) = \arg \max \left[ W^j_d (w, \epsilon, \mu) - \mu - U^{-j} (w, \epsilon, \mu) \right]^{\eta} J (w)^{1-\eta}.
\]  

(15)

### 4.1.4 Steady-State Equilibrium

We now define a steady-state equilibrium of this model. Let \(u^j (\epsilon, \mu)\) denote the steady-state measure of unemployed workers with preference \(\epsilon\) and moving cost \(\mu\) in location \(j\).\(^\text{20}\) We assume free entry of firms. This ensures that in equilibrium, firms expect to make zero profit from creating a vacancy in each market. Equations (16)—(18) describe the zero profit

\(^{19}\)Because of the assumption of risk-neutral preferences and exogenous match destruction, this assumption is innocuous.

\(^{20}\)Derivation of these steady-state unemployment measures are in appendix D.
conditions in the distant and local markets of A and B:

\[
\kappa = q(\theta_j^j) \sum_{i=1}^{N} \frac{\int u^j_i(\mu_i, \epsilon) J(w^j_i(\mu_i, \epsilon))}{\sum_{i=1}^{N} \int u^j_i(\mu_i, \epsilon)}, \quad j \in \{A, B\} \tag{16}
\]

\[
\kappa = q(\theta_d^j) \sum_{i=1}^{N} \frac{\int u^d_j(\mu_i, \epsilon) J(w^d_j(\mu_i, \epsilon)) I_{\{\epsilon > \epsilon_{B,d}(\mu_i)\}}}{\sum_{j=1}^{N} \int u^d_j(\mu_j, \epsilon) I_{\{\epsilon > \epsilon_{B,d}(\mu_i)\}}} \tag{17}
\]

\[
\kappa = q(\theta_d^d) \sum_{i=1}^{N} \frac{\int u^A(\mu_i, \epsilon) J(w^A_d(\mu_i, \epsilon)) I_{\{\epsilon < \epsilon_{A,d}(\mu_i)\}}}{\sum_{j=1}^{N} \int u^A(\mu_j, \epsilon) I_{\{\epsilon < \epsilon_{A,d}(\mu_i)\}}} \tag{18}
\]

**Definition 4.** A steady-state equilibrium consists of

1. value functions \( \{W^j_i, U^j_i, J\}_{j \in \{A,B\}} \),
2. a set of cutoff values \( \{\epsilon_{j,l}, \epsilon_{j,d}\}_{j \in \{A,B\}} \),
3. a set of wages \( \{w^j_l, w^j_d\}_{j \in \{A,B\}} \),
4. a set of steady-state unemployment measures \( \{u^j\}_{j \in \{A,B\}} \),
5. a set of market tightnesses \( \{\theta_l^j, \theta_d^j\}_{j \in \{A,B\}} \),

such that

1. The value functions satisfy equations in (8) and (9),
2. The cutoff values solve (10)–(13),
3. Wages solve the Nash bargaining problems in (14) and (15),
4. Steady-state unemployment measures satisfy the law of for labor market,
5. Market tightnesses satisfy the free-entry conditions in (16)–(18).
Given the tractability of the model, one can derive closed-form equations for the cutoff values and express these values in terms of labor market tightnesses. Further details on computation can be found in appendix D.4.

4.2 Calibration

We have presented a quantitative model to study the effect of compositional changes in the population on migration.\textsuperscript{21} We now turn to the calibration of this model and evaluate the role of population aging in declining migration rates. Each type of worker in the model corresponds to a specific age group in the data. We calibrate the model to match a number of targets related to mobility and labor markets. This section provides the details of the calibration.

4.2.1 Calibration Strategy

The calibration proceeds in two steps. In the first step, we exogenously set values for parameters that have direct counterparts in the data or that can be taken from previous studies because the estimates are not model dependent. The second step uses the Simulated Method of Moments and targets moments computed using data from around the 1980s.

\textsuperscript{21}It is worth emphasizing that the model is general and that it can be used to study the implications of changes in the U.S. population other than the aging population. Some examples are the rise in the share of dual-income households and changes in the homeownership rate. We focus in this paper on the aging of the population, because (1) the magnitude of demographic change is large, (2) the timing lines up well with the trend in migration, and (3) population aging is plausibly exogenous to migration and the labor market.
**Functional Forms:** Following Menzio and Shi (2011) and Schaal (2012), we pick the contact rate functions with a constant elasticity of substitution,

\[ p(\theta) = \theta(1 + \theta^\gamma)^{-\frac{1}{\gamma}}, \quad q(\theta) = (1 + \theta^\gamma)^{-\frac{1}{\gamma}} \]

for both local and distant labor markets. The parameter \(\gamma\) governs the elasticity of the matching function. We assume that the preference for A is distributed according to a normal distribution with a type-specific mean and a constant variance.

**Parameters Calibrated a Priori:** A period in the model corresponds to a month. We focus on seven age groups between the ages of 25 and 59 and set the number of types, \(N\), to seven. These age groups correspond to individuals aged 25–29, 30–34, 35–39, 40–44, 45–49, 50–54, and 55–59. The share of each age group in the population is computed from the March CPS using data in 1981. These shares are reported in column 3 of table 2.

To calibrate the job destruction rate, we take the average of job destruction rates in Shimer (2012) over the period 1950–1985.\(^\text{22}\) As a result, \(\delta\) is set to 3.4 percent. The time discount rate \(\beta\) is set to \(0.99^{1/12} = 0.99916\) to match an annual discount rate of 0.99. The bargaining parameter \(\eta\) is set to 0.5. The flow utility of unemployment is taken from Hall and Milgrom (2008) and set to 0.71.

**Parameters Calibrated with the Simulated Method of Moments:** There are 16 remaining parameters to be estimated. These are the elasticity of the matching function, \(\gamma\), the vacancy posting cost, \(\kappa\), the variance of the preference distribution, the \(\sigma_\epsilon\), means of

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\(^{22}\)These data were constructed by Robert Shimer. For additional details, please see Shimer (2012) and his web page http://sites.google.com/site/robertshimer/research/flows.
the preference distribution for each age group, \( \{E_i\epsilon\}_{i=1}^N \), and the moving cost for each age group, \( \{\mu_i\}_{i=1}^N \). We use a simplex-based algorithm to minimize the percentage deviation of model-generated moments from their empirical counterparts. The parameters and their estimated values are summarized in table 3.

### 4.2.2 Targets

We now describe the empirical targets that we use in the estimation. We target the average job-finding rate, the elasticity of the job-finding rate with respect to market tightness, and the elasticity of out-migration with respect to the local unemployment rate. In the data, the elasticity of out-migration with respect to local unemployment is around 0.21. The model counterpart of this measure is defined as the ratio of the log difference in the outflow of workers divided by the log difference in unemployment rates between A and B. To get estimates of the moving-cost parameter for each type, \( \mu_j \), we target the interstate migration rates for each of the seven age groups in 1981.

Finally, we need to specify how much heterogeneity to generate between A and B in the age composition of the population. To get the targets, we construct for each state-year observation, the share of the seven age groups in that state. We then take the standard deviation of these shares across all observations. We require the difference between the share of age group \( i \) in A and that in B to differ by one standard deviation.

The estimation minimizes the equally weighted sum of squared percentage deviations of model moments from the targets. Table 4 summarizes the moments used in the estimation and provides the fit of the model to the targeted moments.

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\(^{23}\)The mean of \( \epsilon \) for type 4 is normalized to 0 to achieve identification.
4.3 Evaluating the Model’s Performance on Cross-Sectional Facts

Before turning to the implications of an aging population for the time series of migration, we assess the model’s performance on several nontargeted moments. We study the relationship between the age composition and population flows across states and document two new cross-sectional facts. First, states with an older population receive fewer inflows than those with a younger population. Second, for each state we compute the fraction of local hires, defined as the fraction of hires from state residents among all hires in the state. We find this fraction to be higher in states with an older population.\(^\text{24}\) We use these facts to evaluate our estimated model and find it to be quantitatively consistent with both of these facts.

4.3.1 Age Composition and Population Inflows

Our first fact is regarding the cross-sectional relationship between inflows and age composition. Figure 9 reveals a systematic correlation between the age composition and migration flows: states with an older working population, as measured by the fraction of individuals above age 40, have a lower inflow rate. The differences are large: a state with a 10 percentage point higher share of older population receives an inflow that is around 0.9 percentage point lower.

Tables 20 and 21 in appendix A present several regression results measuring the elasticity of inflows with respect to the age composition. The tables further show that the negative relationship is robust to controlling for various state-level variables and fixed effects.\(^\text{25}\) To

---

\(^{24}\)For details on data sources, sample selection, and variable definitions, see appendix C.

\(^{25}\)We also study the relationship between the age composition in a state and outflow rates using data from the SIPP. In particular, we are interested in how the out-migration propensities of two similar individuals that live in states with different age compositions differ. Table 18 reports the marginal effects of various regressors computed from probit regressions. Column (1) shows that among observationally similar individuals, those residing in states with an older population have lower outflow rates. Columns (2) and (3) show a similar fact.
compute the model counterpart of this cross-sectional elasticity, we divide the difference of
the log inflow rates across the two locations by the corresponding difference in the log of
age composition. The results are reported in table 5. The calibrated model is quantitatively
consistent with the cross-sectional relationship.

4.3.2 Age Composition and Fraction of Local Hires

Our second fact pertains to the relationship between the age composition in the population
and hiring patterns across states. Using data from the SIPP, we compute the fraction of
local hires out of total hires for each state-year combination. The number of total hires is
defined as everyone in the state who reports being unemployed three months prior to the
survey month but is employed by the time of the survey. Local hires are then defined as
those among the total hires that did not move across states over this period.

In the data, we compute the elasticity of the share of local hires with respect to the share
of population older than 40. The model counterpart is computed by dividing the difference
of the log of the local hire share across the two locations by the corresponding difference
in the log of age composition. Table 6 summarizes the result of this exercise. We find the
magnitude of the cross-sectional correlation computed in the model to be in line with that
in the data.

4.3.3 Migration Spillovers and the Cross-Sectional Facts

How does the model explain the cross-sectional correlations between age composition and
population flows? Recall that in the model of section 3, an increase in the share of settlers,
across different ages: both young and old individuals living in states with an older population have lower
out-migration rates. Table 19 shows that these relationships are robust to controlling for fixed effects.
that is the share of low-mobility workers, makes it profitable for firms to hire more from the local market. The intuition behind the model’s success in explaining the cross-sectional facts is based on the same mechanism. In the location with an older population, posting a vacancy in the local market is more profitable than posting it in the distant market. Consequently, in the location with the older population, the job-finding rate in the local market is higher and the job-finding rate in the distant market lower. These differences in the recruiting behavior of firms cause the older location to receive fewer inflows. The same mechanism is responsible for the higher local hires in the older location. In this location, firms post a relatively higher share of their vacancies in the local labor market and end up hiring more of their workforce from the resident pool.

It is worth emphasizing that both cross-sectional predictions of the model are due to the general equilibrium effects: firms’ recruiting behavior depends on the age composition of the population. We conclude that the general equilibrium effect is not only important to measuring correctly the effect of aging population on migration, as we find in section 4.4, but also important to understanding key cross-sectional facts.

4.4 Implications of the Aging Population on Interstate Migration

We now use the estimated model to study the implications of the aging U.S. population on interstate migration. Our main result concerns the role of aging in explaining the decline in interstate migration.
4.4.1 Effect of Aging on Aggregate Migration Rates

To evaluate the role of the aging population, we change the shares of each age group to their empirical counterparts in 2010. These shares are reported on the last column of Table 2. We solve for the equilibrium of the estimated model and report equilibrium migration rates. Table 7 reports the results of this exercise. The first row of the table shows that the model generates a decline in interstate migration by 0.9 percentage point. This is about 59 percent of the 1.5 percentage point observed decline in the data.

How much of this decline can be attributed to the migration spillovers? The direct compositional effect can be measured simply by taking the weighted average of 1981 migration rates using the working-age population shares of 2010. This effect accounts for a 0.2 percentage point decline, consistent with the accounting exercise reported in section 2. The remainder of the decline in migration, 0.7 percentage point, should be attributed to the migration spillovers. This large effect can best be understood by focusing on the changes in age-specific migration rates: figure 10 illustrates that our model is able to generate, through only a change in the composition, quite sizable declines in the migration rates of all age groups. This observation suggests that accounting for the general equilibrium effects is important for properly assessing the role of population aging. Studies quantifying only the direct effect of aging on migration understate the effect of the aging of the U.S. population.

4.4.2 Other Predictions of Migration Spillovers: The Share of New Hires Involving Migration

Recall that the model generates a decline in migration through the general equilibrium effect in the labor market. The local job-finding rate increases and the distant job-finding rate
decreases with population aging. Thus, the theory predicts that as the population ages, a larger fraction of hires in the economy should be from the local labor market. To test this prediction, we compute the fraction of hires in CPS in a 12-month period that involves an interstate move. More specifically, we compute the number of workers that report a positive unemployment spell in the last year but are employed at the time of the survey. This is our measure of the total number of hires. We then divide the number of workers in this group that also report an interstate move by total hires. Figure 11 shows the time series of this measure and provides evidence in favor of the theory.

To compare the quantitative predictions of the model with the data, in table 8, we report the model counterpart of the fraction of hires involving an interstate move in 1981 and 2010, and compare them to the data. As table 8 shows, the model generates a 46 percent decline in hires with an interstate move, the same in magnitude as the decline in the data.

### 4.4.3 The Decline in Migration and Aggregate Unemployment

A common concern is that lower migration rates might cause higher aggregate unemployment. One popular theory is that a decline in migration might indicate a lower ability of workers to take on distant jobs, which in turn can cause aggregate unemployment to rise. This concern is particularly important in the context of our model, because migration in the model is directly linked to job offers from the distant location. Moreover, the model predicts a large decline in migration due to aging. This decline might suggest that aging causes an increase in unemployment. Based on these concerns, we use the estimated model to study the implications of aging for aggregate unemployment.

Table 9 reports the aggregate unemployment rate in the model. Despite a large drop in
migration, unemployment increases only slightly in 2010 over that in 1980. As we explained earlier, migration decreases because firms post more jobs aimed at attracting local workers. Workers are not moving as much because they have less incentive to move to find jobs. This seemingly counterintuitive result on the unemployment rate arises because the increase in local job-finding rates partly offsets the negative effect from the compositional change.

5 Conclusion

This paper has studied the long-run decline in interstate migration. We showed analytically that there is a positive composition externality of workers with high moving costs on the local labor market. As the share of these workers increases, local jobs become easier to find and the migration rates of all workers decline in equilibrium. This mechanism illustrates that changes in population composition have not only a direct effect on migration but also an indirect effect through general equilibrium.

Our quantitative analysis suggests that population aging explains nearly two-thirds of the decline in the data, and that most of this decline is accounted for by the general equilibrium effect. We also find that the general equilibrium effect is important in understanding several cross-sectional facts about population flows and the age-composition across states.

The migration spillover effect defined by this paper has implications for other themes in the mobility literature. One line of literature examines the effect of housing market imperfections on labor mobility. Our theory implies that these imperfections may also affect the migration rate of renters. Therefore, one cannot identify the effect of housing market imperfections on labor mobility by treating renters as the control group and homeowners.
as the treatment group. Another important trend in the labor market in the United States is the long-run decline in job-to-job transitions. A large fraction of this decline in the labor turnover rate is due to the within-group component. We think that a similar general equilibrium effect might be in place, and that the aging population may have larger impact on the decline in labor turnover than the direct compositional effect. We plan to investigate these issues in further research.

6 Tables

<table>
<thead>
<tr>
<th>Table 1</th>
<th>Mobility and the Age Composition</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Panel A: OLS</strong></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Aggregate</td>
</tr>
<tr>
<td>Share 40-60</td>
<td>$-1.8102^{***}$</td>
</tr>
<tr>
<td></td>
<td>(0.512)</td>
</tr>
<tr>
<td>Time dummies</td>
<td>Yes</td>
</tr>
<tr>
<td>State dummies</td>
<td>Yes</td>
</tr>
<tr>
<td>$R^2$</td>
<td>0.686</td>
</tr>
<tr>
<td>$N$</td>
<td>1,127</td>
</tr>
</tbody>
</table>

| **Panel B: IV** | | |
| | Aggregate | 25-40 | 40-60 |
| Share 40-60 | $-3.7902^{**}$ | $-3.7671^{**}$ | $-5.9853^{***}$ |
| | (1.655) | (1.850) | (2.258) |
| Time dummies | Yes | Yes | Yes |
| State dummies | Yes | Yes | Yes |
| $R^2$ | 0.686 | 0.626 | 0.465 |
| $N$ | 1,127 | 1,124 | 1,096 |
### Table 2
**Migration rates across age groups**

<table>
<thead>
<tr>
<th>Age group</th>
<th>Average interstate migration rate</th>
<th>Share in 1980</th>
<th>Share in 2010</th>
</tr>
</thead>
<tbody>
<tr>
<td>25-29</td>
<td>5.0%</td>
<td>19.9%</td>
<td>13.0%</td>
</tr>
<tr>
<td>30-34</td>
<td>3.5%</td>
<td>18.4%</td>
<td>13.8%</td>
</tr>
<tr>
<td>35-39</td>
<td>2.6%</td>
<td>15.3%</td>
<td>14.6%</td>
</tr>
<tr>
<td>40-44</td>
<td>1.9%</td>
<td>12.4%</td>
<td>15.2%</td>
</tr>
<tr>
<td>45-49</td>
<td>1.5%</td>
<td>11.0%</td>
<td>15.7%</td>
</tr>
<tr>
<td>50-54</td>
<td>1.3%</td>
<td>11.5%</td>
<td>14.1%</td>
</tr>
<tr>
<td>55-59</td>
<td>1.2%</td>
<td>11.6%</td>
<td>13.6%</td>
</tr>
</tbody>
</table>

Note: Table 2 shows migration rates for people in various age groups computed over the period 1980-1985. Source: March CPS and authors’ calculations.

### Table 3
**Model Parameters**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Pre-calibrated</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\beta$</td>
<td>0.99^{1/12}</td>
<td>time discount rate</td>
</tr>
<tr>
<td>$\delta$</td>
<td>3.4%</td>
<td>job destruction probability</td>
</tr>
<tr>
<td>$b$</td>
<td>0.71</td>
<td>flow utility of being unemployed</td>
</tr>
<tr>
<td>$\eta$</td>
<td>0.5</td>
<td>Nash Bargaining power of workers</td>
</tr>
<tr>
<td><strong>Within-the-Model</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\gamma$</td>
<td>1.1</td>
<td>elasticity of matching function</td>
</tr>
<tr>
<td>$\kappa$</td>
<td>0.24</td>
<td>cost of posting a vacancy</td>
</tr>
<tr>
<td>$\sigma_\epsilon$</td>
<td>0.0006</td>
<td>standard deviation of preference type</td>
</tr>
<tr>
<td>$E\epsilon_1$</td>
<td>-0.0007</td>
<td>mean of preference distribution by age group</td>
</tr>
<tr>
<td>$E\epsilon_2$</td>
<td>-0.0008</td>
<td></td>
</tr>
<tr>
<td>$E\epsilon_3$</td>
<td>-0.0015</td>
<td></td>
</tr>
<tr>
<td>$E\epsilon_5$</td>
<td>0.0012</td>
<td></td>
</tr>
<tr>
<td>$E\epsilon_6$</td>
<td>0.0013</td>
<td></td>
</tr>
<tr>
<td>$E\epsilon_7$</td>
<td>0.0016</td>
<td></td>
</tr>
<tr>
<td>$\mu_1$</td>
<td>0.11</td>
<td>moving cost by age group</td>
</tr>
<tr>
<td>$\mu_2$</td>
<td>0.20</td>
<td></td>
</tr>
<tr>
<td>$\mu_3$</td>
<td>0.25</td>
<td></td>
</tr>
<tr>
<td>$\mu_4$</td>
<td>0.31</td>
<td></td>
</tr>
<tr>
<td>$\mu_5$</td>
<td>0.32</td>
<td></td>
</tr>
<tr>
<td>$\mu_6$</td>
<td>0.42</td>
<td></td>
</tr>
<tr>
<td>$\mu_7$</td>
<td>0.42</td>
<td></td>
</tr>
</tbody>
</table>

Note: Table 3 reports the estimated values of model parameters.
Table 4
Matching the Calibration Targets

<table>
<thead>
<tr>
<th>Moment</th>
<th>Data</th>
<th>Model</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average job finding rate</td>
<td>0.395</td>
<td>0.398</td>
</tr>
<tr>
<td>Elasticity of job finding rate w.r.t. market tightness</td>
<td>0.72</td>
<td>0.79</td>
</tr>
<tr>
<td>Elasticity of out migration w.r.t. local unemployment rate</td>
<td>0.21</td>
<td>0.42</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Annual migration rate by age group</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>25 − 29</td>
<td>5.42%</td>
<td>5.21%</td>
</tr>
<tr>
<td>30 − 34</td>
<td>3.93%</td>
<td>3.98%</td>
</tr>
<tr>
<td>35 − 39</td>
<td>3.06%</td>
<td>2.87%</td>
</tr>
<tr>
<td>40 − 45</td>
<td>2.03%</td>
<td>2.30%</td>
</tr>
<tr>
<td>45 − 49</td>
<td>1.97%</td>
<td>2.06%</td>
</tr>
<tr>
<td>50 − 54</td>
<td>1.44%</td>
<td>1.48%</td>
</tr>
<tr>
<td>55 − 59</td>
<td>1.43%</td>
<td>1.43%</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Population share difference by age group: A-B</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>25 − 29</td>
<td>1.03%</td>
<td>0.96%</td>
</tr>
<tr>
<td>30 − 34</td>
<td>0.90%</td>
<td>0.81%</td>
</tr>
<tr>
<td>35 − 39</td>
<td>1.37%</td>
<td>1.59%</td>
</tr>
<tr>
<td>40 − 45</td>
<td>−0.63%</td>
<td>−0.22%</td>
</tr>
<tr>
<td>45 − 49</td>
<td>−0.85%</td>
<td>−0.88%</td>
</tr>
<tr>
<td>50 − 54</td>
<td>−0.96%</td>
<td>−1.0%</td>
</tr>
<tr>
<td>55 − 59</td>
<td>−1.35%</td>
<td>−1.70%</td>
</tr>
</tbody>
</table>

Note: Table 4 shows the model’s fit on targeted moments of the data.

Table 5
Elasticity of Inflows: Model vs. Data

<table>
<thead>
<tr>
<th>Elasticity of the inflow rate w.r.t. share of population &gt; 40</th>
<th>Data</th>
<th>Model</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>−4.42</td>
<td>−4.83</td>
</tr>
</tbody>
</table>

Table 6
Elasticity of the Local Hires: Model vs. Data

<table>
<thead>
<tr>
<th>Elasticity of the share of local hires w.r.t. share of population &gt; 40</th>
<th>Data</th>
<th>Model</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0.475</td>
<td>0.424</td>
</tr>
</tbody>
</table>

(0.209)
Table 7
Migration: Data vs. Model

<table>
<thead>
<tr>
<th></th>
<th>Data</th>
<th></th>
<th>Model</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Aggregate interstate migration</td>
<td>3.08%</td>
<td>1.56%</td>
<td>3.0%</td>
<td>2.1%</td>
</tr>
<tr>
<td>Interstate migration rate by age group</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>25 – 29</td>
<td>5.4%</td>
<td>3.3%</td>
<td>5.2%</td>
<td>4.4%</td>
</tr>
<tr>
<td>30 – 34</td>
<td>3.9%</td>
<td>2.3%</td>
<td>4.0%</td>
<td>3.2%</td>
</tr>
<tr>
<td>35 – 39</td>
<td>3.1%</td>
<td>1.6%</td>
<td>2.9%</td>
<td>2.2%</td>
</tr>
<tr>
<td>40 – 45</td>
<td>2.0%</td>
<td>1.0%</td>
<td>2.3%</td>
<td>1.6%</td>
</tr>
<tr>
<td>45 – 49</td>
<td>2.0%</td>
<td>0.9%</td>
<td>2.1%</td>
<td>1.6%</td>
</tr>
<tr>
<td>50 – 54</td>
<td>1.4%</td>
<td>0.8%</td>
<td>1.5%</td>
<td>1.1%</td>
</tr>
<tr>
<td>55 – 59</td>
<td>1.4%</td>
<td>0.8%</td>
<td>1.4%</td>
<td>1.1%</td>
</tr>
</tbody>
</table>

Note: Table 7 reports aggregate and age-specific migration rates in 1981 and 2010. Annual migration in the model is computed as the fraction of all population who move at least once in a 12-month period. Data counterpart is computed from the March CPS and detrended using an HP filter with a scaling parameter of 100.

Table 8
Fraction of Hires with an Interstate Move: Data vs. Model

<table>
<thead>
<tr>
<th></th>
<th>Data</th>
<th>Model</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fraction of local hires in 1980, %</td>
<td>7.0</td>
<td>8.9</td>
</tr>
<tr>
<td>Fraction of local hires in 2010, %</td>
<td>3.7</td>
<td>4.8</td>
</tr>
<tr>
<td>Change: 1980-2010</td>
<td>-47%</td>
<td>-46%</td>
</tr>
</tbody>
</table>

Note: Table 8 shows the predictions of the model for the fraction of hires involving an interstate move and compares it to the data from the CPS. The last row shows that the model generates a decline quantitatively similar to that in the data.
<table>
<thead>
<tr>
<th>Ageing Population and Unemployment</th>
</tr>
</thead>
<tbody>
<tr>
<td>1980</td>
</tr>
<tr>
<td>-------------------</td>
</tr>
<tr>
<td>Aggregate unemployment rate, %</td>
</tr>
</tbody>
</table>

Note: Table 9 shows the implications of the aging population for the aggregate unemployment rate in the model.

7 Figures

**Figure 1**
Interstate Migration in the United States

Note: Figure 1 shows the time series of annual interstate migration rates computed from the March CPS. The blue line is the migration rate in the March CPS for the period 1970-2012. Migration rates are computed based on non-imputed observations. The solid red line is the long-run trend of interstate migration rates using Hodrick-Prescott filter for the period 1980-2012.
Figure 2
Spatial Nature of Migration Rates

Outflow Rate
- [0.0, 0.7]
- [0.7, 1.5]
- [1.5, 2.5]
- [2.5, 4]
- [4, 10]
Figure 3
Reasons to Move in the United States

Note: Figure 3 shows the fraction of the working-age population that moved across states for different reasons, computed from the March CPS. The red line is the share of migrants who moved for job-related reasons. The blue line is the fraction of moves related to family reasons. The green line is the share of migrations for all other reasons.

Figure 4
Aging Population in the United States

Note: Figure 4 shows the aging of the U.S. population over the period 1980-2010. The blue dots indicate the share of individuals older than 40 among individuals between the ages of 25 and 60. The red squares show interstate migration rates during the same time period (March CPS; authors’ calculations).
**Figure 5**

**Interstate Migration over Working Ages**

Note: Figure 5 shows annual interstate migration rates over the working life. Migration rates are computed based on non-imputed observations. The interstate migration rate decreases sharply over the working life and most of the decline occurs before age 40.

**Figure 6**

**Quantifying the Direct Effect of Aging on Interstate Migration**

Note: Figure 6 shows the direct effect of the aging population on interstate migration. The blue line with circles is the interstate migration rate in the March CPS. The red line shows the counterfactual migration rate obtained by fixing the migration rate of each age group to its 1980 level and changing the share of each group in line with the data (March CPS; authors’ calculations).
Figure 7
TIME TREND OF INTERSTATE MIGRATION OVER WORKING AGES

Note: Figure 7 shows the 5-year moving average of interstate migration rates for each age group.

Figure 8
MARKET SEGMENTATION AND THE MIGRATION SPILOVERS

Note: Figure 8 shows the importance of the market structure for the existence of the spillover effect. In solid blue line, we plot the relationship between the fraction of immobile workers and the equilibrium migration rate of mobile workers. The dashed red line shows the same relationship for a model with complete market segmentation in the local labor market ($\rho = 1$). Finally, the dashed-dotted green line shows an intermediate case, where $\rho = 0.5$. This figure clearly shows that the migration spillover effect does not exist in a model with perfect market segmentation. The degree of the spillovers, as measured by the slope of the line, is decreasing in the extent of market segmentation.
Note: Figure 9 shows the cross-sectional relationship between the fraction of older population and the inflow rate across states. We first group the states in 10 percentiles according to the fraction of individuals older than 40. The x-axis is the mean of this fraction over all states in a percentile, whereas the y-axis is the average inflow rate of states in a percentile. The figure shows that states with a higher fraction of older population receive less inflows. Source: IRS population flows, March CPS, and authors’ calculations.

Note: Figure 10 shows the migration rates of different age groups from the data and compare the model counterparts. The x-axis is the seven age groups used in our estimation. The y-axis is the migration rate. The blue dashed line is the migration rate of each age group in 1980 and the black dashed line is for 2010. The green solid line is computed from the estimated model with population share of 2010.
Figure 11
Fraction of Hires Involving an Interstate Move

Note: Figure 11 shows the time series of the fraction of hires that involve an interstate move. The denominator is the number of individuals aged 25-59 that report a positive number of weeks of unemployment in the last year. The numerator is those that also report an interstate move (March CPS and authors' calculations).
Chapter II

Geographical Reallocation and

Unemployment during the Great Recession:

the Role of the Housing Bust

8 Introduction

The unemployment rate in the United States increased from 5 percent in January 2007 to 10.1 percent in October 2009, as the economy experienced its deepest downturn in the postwar era. Equally important, but less well known and understood, is the fact that the unemployment rates varied widely across locations. For example, the difference between the 90th and the 10th percentiles in the unemployment rate distribution more than doubled.\textsuperscript{27} During the same period, following a sharp decline in house prices, the net migration rate declined by 50 percent to an all-time low.\textsuperscript{28} In this paper, we develop a novel general equilibrium model of multiple locations with frictional housing and labor markets and use it to argue that the decline in the geographical reallocation of labor, triggered by the housing bust, caused the rise in unemployment dispersion across locations. We then use the model

\textsuperscript{26}This chapter is co-authored with Y. Fatih Karahan. The views expressed in this paper are those of the authors and do not necessarily reflect the position of the Federal Reserve Bank of New York or the Federal Reserve System.

\textsuperscript{27}Throughout the paper, a location refers to a Metropolitan Statistical Area (MSA) in the United States. The average of the 90–10 differential across MSAs over the period 2000–2007 is 3 percent, whereas the average over the period 2008–2010 is 7 percent.

\textsuperscript{28}Data on population flows are obtained from the IRS. For further details about the data used in this paper and the definitions, please see Appendix E.
to measure the effect of the housing bust on aggregate unemployment during the Great Recession.

How and why does a decline in house prices affect geographical reallocation and the labor market? In this paper, we focus on a financial friction: the down payment requirement for purchasing a home. When house prices fall, the amount of home equity declines, making it harder for homeowners to afford the down payment on a new house after a move. To the extent that households care about owning a house, the decline in house prices affects their migration decisions. Some households that would normally move out of low-productivity regions may stay and look for jobs in distressed labor markets, further increasing local unemployment in those regions. Thus, the decline in geographical reallocation may cause unemployment to rise differently in different places. Furthermore, by increasing the fraction of population in low-productivity locations, the housing bust may cause aggregate unemployment to rise more.

Our economy consists of a finite number of locations populated by workers and firms. Each location has local labor and housing markets that are subject to search frictions and exogenous productivity shocks. Workers reside in different locations and may choose to move for a combination of idiosyncratic reasons and conditions in the labor and housing markets. Once in a location, workers may decide to purchase a home or remain as renters. To finance housing purchases, they can take on a mortgage after making a down payment from their savings.

We then proceed to structurally estimating a two-location version of our model using the simulated method of moments. Specifically, we target national gross and net migration rates, homeownership rates, median leverage, average time for selling a house, and aggre-
gate statistics related to the labor market before the Great Recession. The calibrated model is quantitatively consistent with a range of other facts that are not explicitly targeted in the estimation. These include the correlation between leverage and mobility, the cyclical-ity of migration and unemployment dispersion, and the negative correlation between local unemployment and net flows.

We then use the model to study the role of the housing bust in the geographical dispersion of unemployment during the Great Recession. To that extent, we first group the Metropolitan Statistical Areas (MSAs) in the United States into two categories according to the decline in house prices during the housing bust. The decline in labor productivity is larger for the group with the larger housing bust. We isolate the impact of the housing bust by feeding into the model the observed declines in labor productivities for the two locations with and without the associated changes in house prices.

Our quantitative exercise shows that the model captures well the decline in migration rates during the Great Recession. We document that the net migration rate decreased from 0.8 percent in 2006 to 0.3 percent in 2009. In the model, we find that the housing bust and the recession resulted in a decline in net migration from a prerecession average of 0.8 percent to 0.2 percent. Moreover, the model predicts that, absent the housing bust, migration rates would have increased.\(^{29}\) That increase occurs because the productivity shock is heterogeneous across locations, which raises the incentives to migrate out of the low-productivity location. The decline in house prices counteracts this force by decreasing the home equity of homeowners and making the down payment constraint a relevant friction. As

\(^{29}\)Kaplan and Schulhofer-Wohl (2012) have shown that most of the decline in gross migration during the Great Recession is a consequence of a secular trend, implying a small cyclical component. Our findings suggest that the decline in migration observed during this period constitutes only a small portion of the effect of the housing bust.
households value owning over renting, many unemployed workers who would have otherwise migrated to the better location decide to stay. Quantitatively, the latter effect dominates the former and results in a decline in geographical reallocation.

The decline in migration due to “house-lock” has implications for the dispersion of unemployment across the two locations. In particular, by reducing the flow of unemployed workers out of the high-unemployment location, it drives a wedge between the two locations. Quantitatively, we find that the combination of house price and labor productivity shocks is able to generate almost 90 percent of the difference in unemployment rates between the two locations during the Great Recession.

It has been suggested that the decline in geographical mobility due to locked-in homeowners might be responsible for the sluggish performance of the labor market during the Great Recession. The model developed in this paper enables us to quantify the aggregate impacts of a house price decline through its effects on geographical reallocation. Our counterfactual experiment suggests that the unemployment rate in the United States would have been 0.5 percentage points lower throughout the recession and during the recovery had it not been for the decline in house prices. Equivalently, the housing bust explains about 10 percent of the increase in unemployment during the Great Recession. It is worth mentioning that the estimated aggregate impact is smaller than one might expect, given the large drop in net migration and the sharp rise in the dispersion of unemployment. However, this finding can be easily reconciled by noting that the housing bust has opposite effects on the two locations: the low-productivity location has higher unemployment than in a recession without a housing bust because of the locked-in unemployed homeowners, whereas the other loca-

\[30\text{e.g. see Kocherlakota (2010).}\]
tion has lower unemployment, thanks to the lack of the inflow of unemployed coming from the low-productivity location. Thus, it is not clear ex ante whether one should expect the reduced geographical reallocation to cause higher or lower level of aggregate unemployment. Our quantitative exercise suggests that while this mechanism results in a rise in aggregate unemployment, it is quantitatively small.

This paper is related to several strands of the literature. There is a large literature studying how regions react to adverse labor market shocks. Blanchard and Katz (1992) have documented that the effect of an adverse shock on local unemployment is persistent in the short run and mean-reverting in the long run but that the effect on employment is permanent. They conclude that population flows are an important adjustment mechanism. Our paper builds on the premise that geographical reallocation is important for local economies and considers the effects of potential frictions for mobility on local and aggregate unemployment.

A growing literature studies the effects of housing equity, house-selling behavior, and mobility. In a seminal work, Stein (1995) analyzes a simple model with a downpayment requirement and finds collateral constraints prevent mobility when house prices decline. Using data from the Boston condominium market in the 1990s, Genesove and Mayer (1997) document a positive relation between leverage and the posting price of houses. They find that a homeowner with a 100 percent leverage posts a 4 percent higher price compared to an otherwise similar homeowner with only 80 percent leverage, and it takes about 15 percent longer for a highly leveraged homeowner to sell the housing unit. Consistent with their findings, our model successfully captures the relationship between leverage and the time to sell. Using mortgage data from New Jersey, Chan (2001) finds that declining house prices significantly reduce the mobility rates of homeowners, in particular for those with
a high loan-to-value ratio. More recently, using the American Housing Survey, Schulhofer-Wohl (2011) finds no relationship between leverage and residential mobility, whereas Ferreira et al. (2010, 2012) find that homeowners with negative equity move 30 percent less compared to homeowners with positive equity.

On the theoretical front, our model builds on the island framework of Lucas and Prescott (1974) and Alvarez and Shimer (2011). Head and Lloyd-Ellis (2012) is one of several recent papers studying the interactions among the housing market, migration, and the labor market. They study a model of multiple locations with search frictions in housing and labor markets and show that the illiquidity of housing can generate differences in unemployment rates and homeownership rates. Our paper is different from theirs, as we focus on the role of mortgage leverage in explaining population flows during the Great Recession, whereas they analyze a stationary environment with no assets. This approach requires deviation from a steady-state analysis by incorporating location-specific productivity shocks and allowing for asset accumulation.

A number of recent papers study the role of housing in labor reallocation. Nenov (2012) builds a multiregional economy with a fixed supply of housing and uses it to study the effects of lower mobility on labor market outcomes. In his model, the migration rate is determined by the exogenous fraction of immobile households. Our paper models the determinants of the decline in mobility and is thus able to isolate the relevance of the frictions coming from the housing market. Davis et al. (2010) build a model with a continuum of locations and use it to study the role of moving costs and inelastic housing supply on shaping the character and extent of labor reallocation in the United States.

Recently, several papers have studied the effect of the house-lock on aggregate unem-
ployment. Sterk (2011) uses a business cycle model with a down payment requirement. In his model, a constant fraction of job offers requires households to move and buy a new house. Falling house prices make the housing transaction undesirable, reducing mobility and resulting in higher aggregate unemployment. Unlike in Sterk (2011), we explicitly model local labor markets. This modeling allows us to endogenize the importance of migration for aggregate unemployment in an environment with heterogeneous labor productivity shocks. Our findings suggest that, absent housing market related frictions, migration would have increased in response to local productivity differences. This increase implies that geographical reallocation is more important for the labor market during the Great Recession. Sahin et al. (2012) develop a measure of mismatch and quantify the extent of unemployment caused by mismatch across industries and locations during the Great Recession. They find that mismatch can account for 0.6 to 1.7 percentage points of the aggregate unemployment rate during the Great Recession but that most of the increase in structural unemployment is sectoral.

To assess the quantitative importance of the house-lock hypothesis empirically, several recent papers investigate differences in the migration rates and labor market outcomes of homeowners and renters. Kothari et al. (2012) use mobility differences between homeowners and renters to construct an upper bound on the effect of mobility on unemployment during the Great Recession. Aaronson and Davis (2011) compare the evolution of migration rates of homeowners and renters to measure the effect of the housing bust on geographical mobility. Valletta (2012) assesses the importance of house-lock by focusing on unemployment durations of homeowners and renters across geographic areas differentiated by the severity of the decline in home prices. These studies find only small differences in the geographi-
ical mobility and labor market outcomes between homeowners and renters, and conclude that the effect of the housing bust on migration and unemployment has been economically insignificant. An important identifying assumption common to all of these studies is that renters’ migration behavior is not affected by the decline in house prices. In Karahan and Rhee (2014), we show that there can be substantial spillover effects, i.e., a decline in the migration rate of one group (treatment group, say, homeowners) may induce a decline in the migration rate of the rest of the economy (control group, say, renters), thanks to general equilibrium effects in the labor market. More strikingly, the decline in the migration rate of the control group may be larger than that of the treatment group. Therefore, we do not view the aforementioned studies as contradicting the main mechanism pursued in this paper.\footnote{The mechanism is as follows: All else equal, firms prefer hiring low-mobility workers as they tend to have a lower outside option and tend to stay longer on the job. When the migration rate of a group of workers decreases, expected profits increase in the local labor market, which tends to have a larger share of low-mobility workers. Consequently, firms shy away hiring people from distant labor markets and end up posting more jobs and hiring more workers in the local labor market. This substitution in the vacancy posting behavior of firms results in lower mobility for all workers in the economy. While the model in this paper assumes away this potentially important linkage, it is possible to enrich the model and incorporate this mechanism that can then generate declines in renter migration consistent with the data.}

Finally, this paper is part of a recent literature that employs directed search models of the labor market to study economies with heterogeneity and aggregate shocks (e.g., Menzio and Shi (2010b,a, 2011); Schaal (2012); Kaas and Kircher (2011)). In our model, both the housing and the labor market is modeled with directed search. The use of directed search enables us to compute a block-recursive equilibrium of the model; that is, a particular recursive equilibrium, in which the endogenous distributions generated within the model are not part of the state space. Along this dimension, most closely related to us is Hedlund (2012), who develops a directed search model of the housing market and studies the implications of
search frictions on house price dynamics.

The rest of the paper is organized as follows. Section 9 presents the model. Section 10 provides the details of our estimation and the model’s fit along the targeted and untargeted dimensions of the data. Section 11 uses the model as a measurement tool to quantify the effect of the housing bust on the labor market. Finally, Section 12 concludes.

9 A Model of Labor and Housing Markets and Geographical Reallocation

In this section, we present a model of geographical reallocation. To illustrate the relationship between households’ leverage and migration decision, we adopt a directed search model of the housing market. Facing a trade-off between the posting price and the time it takes to sell a house, households decide the posting price for their houses. As a by-product of directed search, we are able show that our model admits a block-recursive equilibrium: that is, a particular recursive equilibrium, in which the endogenous distributions generated within the model are not part of the state space.

9.1 Agents and Markets

The economy consists of a finite number of locations indexed by $i \in I$. There is a continuum of households of measure 1 located in different locations. There is a continuum of firms, housing market intermediaries (real estate managers and leasing companies), and construction companies with a positive measure. Time is discrete and continues forever: $t = 0, 1, 2, \cdots$.  

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Households: Households are ex ante identical and have a periodical utility function given by \( u(c, l, h, \chi_i) \),
\[
u : \mathbb{R}_+ \times \{l_0, l_1\} \times \{h_0, h_1\} \times [\chi, \chi] \to \mathbb{R},
\]
defined over consumption \( c \), leisure \( l \), housing status \( h \), and preference for their current residence \( \chi_i \). Leisure takes a value of \( l_0 \) or \( l_1 \) where \( l_0 < l_1 \), denoting whether the household is employed or unemployed, respectively. Similarly, housing status takes values \( h_0 \) or \( h_1 \) with \( h_0 < h_1 \), denoting whether the household is a renter or a homeowner, respectively. Households decide where to live and work, whether to purchase a house or live in a rented one and how much to save and consume. Each household maximizes the expected sum of periodical utilities discounted at the discount rate \( \beta \in (0, 1) \).

Firms and the Labor Market: Each firm operates a constant returns-to-scale technology that, if matched with a worker, turns one unit of labor into \( z_i \) units of consumption. The labor productivity \( z_i \) is the same for all firms in a given location but can be different across locations. Labor productivity in a location follows a Markov process and takes values in \( Z = \{z_1, z_2, \cdots, z_N\} \), according to the transition matrix \( \Upsilon_Z \). At the beginning of each period, the state of the economy, \( \psi \), is given by
\[
\psi = (\{z_i\}_{i \in I}, \{n_i\}_{i \in I}, \{\Gamma_i\}_{i \in I}).
\]
The first element of \( \psi \) denotes labor productivities at each location; \( n_i \) is the fraction of population in location \( i \), and \( \Gamma_i : \mathbb{R} \times \{h_0, h_1\} \times \mathbb{R}_+ \times \{l_0, l_1\} \times [\chi, \chi]^I \to [0, 1] \) is a function denoting the measure of households in location \( i \) over assets, housing tenure, wages,
employment status, and location preference.

Households and firms meet and produce output in a frictional labor market. The labor market is organized along a continuum of submarkets that differ in the wage contract that is offered. More specifically, we allow only for fixed-wage contracts. When a firm meets a worker in submarket $w$, the firm offers the worker an employment contract that pays the worker a wage of $w$ every period until the match ends exogenously with probability $\delta$. Firms and workers fully commit to this contract. Consequently, each submarket can be indexed by the wage offered $w$.

Search in the labor market is directed: firms choose the wage to offer to potential workers and the number of vacancies to post. Each vacancy requires the payment of a posting cost, $k$. Similarly, households decide in which submarket to look for jobs. We denote by $\theta_i^f(w; \psi)$ the market tightness of submarket $w$—the ratio of the number of vacancies created by firms in submarket $w$ to the number of workers that are looking for jobs in the same submarket in location $i$. Once in a submarket, workers find jobs with probability $\pi_l[\theta_i^f(w; \psi)]$, and firms find workers with probability $q_l[\theta_i^f(w; \psi)] = \pi_l[\theta_i^f(w; \psi)]/\theta_i^f(w; \psi)$.

**Housing Market Intermediaries and the Structure of the Housing Market:** There are three types of companies in the housing market: construction companies, real estate managers (REMs), and leasing companies. Construction companies operate a constant returns-to-scale technology that turns $\mu_i$ units of the consumption good into one unit of housing in location $i$. Newly constructed houses can be sold to households or to leasing companies to be used as rental units. $\mu_i$ is assumed to be constant over time. We model the housing bust as an unexpected decrease in construction costs.
Housing transactions are facilitated by REMs in that they buy houses from sellers and sell them to buyers. In both of these markets, households and REMs meet in a frictional housing market. Similar to the labor market, the housing market consists of a continuum of submarkets. Each submarket is characterized by the transaction price of the house, \( p \).

Search is directed in the housing market. Renters that would like to buy a house decide on the price at which they are willing to buy and look for a house in that submarket. There is a down payment requirement to purchasing a house: households are allowed to buy a house at price \( p \) only if their assets suffice to cover \( \alpha \) fraction of the house price; i.e., \( a \geq \alpha p \).

REMs with a house decide on the selling price and post a vacancy accordingly. We define the market tightness of submarket \( p, \theta_b^i (p; \psi) \), as the ratio of vacancies posted by REMs at price \( p \) to the number of households that are looking for a house at this price. Once in a submarket, households meet an REM and buys a house with probability \( \pi_b[\theta_b^i (p; \psi)] \). The probability for a REM of meeting a household is given by \( q_b[\theta_b^i (p; \psi)] = \pi_b[\theta_b^i (p; \psi)]/\theta_b^i (p; \psi) \).

The directed nature of the search ensures that upon meeting a REM, a household is willing to buy the house at price \( p \).

On the other side of the housing market, homeowners that would like to sell their house choose a selling price \( p \). REMs decide the price to buy and look for sellers that are willing to sell at that price. The market tightness on this side of the housing market is denoted by \( \theta_s^i (p; \psi) \). The probability of a trade for a seller is given by \( \pi_s[\theta_s^i (p; \psi)] \), and the probability of a trade for the REM is given by \( q_s[\theta_s^i (p; \psi)] = \pi_s[\theta_s^i (p; \psi)]/\theta_s^i (p; \psi) \).

Leasing companies buy houses from construction companies and turn them into rental houses at no cost. They then rent them out to households for one period to obtain a rent of \( \rho^i (\psi) \). The market for rental units is perfectly competitive. Finally, rental units depreciate:
a rental unit disappears every period with probability $\gamma$.

**Financial Markets:** Financial markets are incomplete. Households can save and borrow using a risk-free bond. The risk-free bond yields a constant interest rate $r$. When borrowing, homeowners and renters face (exogenously) different borrowing limits $a_1$ and $a_0$, where $a_1$ is the borrowing limit of homeowners and $a_0$ is the borrowing limit of renters. The borrowing limit is tighter for renters, $a_0 > a_1$.

Renters may use a mortgage to buy a house. As mentioned previously, households can purchase a house at price $p$, as long as their assets are larger than $\alpha p$. The portion of the house price that is not paid at the time of purchase is borrowed at interest rate $r$. Households can then roll over their debt by paying the interest only or lower their balance by paying more every period. The details of the mortgage arrangement will be further explained in Section 9.3.

### 9.2 Timing of Events

The introduction of assets into a search model with aggregate shocks increases the dimensionality of workers’ and firms’ problems. In principle, the aggregate state includes the labor productivity shocks across locations, $\{z_i\}_{i \in I}$, and the population distribution, as well as the distribution of employment, wages, assets, preference shocks, and housing status within each location. The latter is critical because one must keep track of an infinite dimensional object in the state space, rendering the dynamics of the model computationally intractable. Fortunately, the structure of the model gives rise to a block-recursive equilibrium, an equilibrium in which firms’ and workers’ problems are independent of the distribution. We present the
model in its general form and allow the distribution to be part of the state space. We then discuss, in the next section, what conditions give rise to this property.

Each period is divided into five stages: job separations, housing market transactions, migration, search in the labor market, and production. During the separation stage, employed households exogenously move into unemployment with probability $\delta$.

After shocks are realized, housing markets open. If a homeowner wants to sell his house, he chooses the price to sell and looks for a buyer. If the homeowner successfully sells his unit, he becomes a renter for one period but may enter the housing market in the next period. If a renter wants to purchase a house, he chooses at what price to look for a house and visits the corresponding submarket to find a seller.

Upon completing housing transactions, households decide whether to remain in their current location or to move to another place. Unemployed renters and unemployed homeowners that sold their houses within this period decide whether and where to move.

Following the migration stage, labor markets open. Firms post vacancies in different submarkets, and unemployed households choose in which submarket to look for a job. Job search is local: only residents of location $i$ are allowed to apply for vacancies posted in location $i$.

During the production stage, an unemployed household collects $b$ units of the consumption good as unemployment benefits. Employed households in location $i$ produce $z_i$ units of output and are paid their wage $w$. Households then decide on their consumption and savings, and renters pay out the location-specific rent $\rho^i(\psi)$.
9.3 The Problem of the Household

In this section, we present the Bellman equations that govern the decision problems of households. The value functions are measured at the beginning of the consumption-savings stage—the last stage in a period. We use auxiliary value functions to denote the value functions at the job search stage and define them when necessary. We first consider the problem of an unemployed renter.

9.3.1 The Consumption-Savings Problem

We start by describing the problem at the consumption-savings stage. The search problem of buyers and sellers in the housing market is also explained in this section. We then turn to the search problem in the labor market.

Unemployed Renters: Equation (19) presents the problem of an unemployed renter at the consumption-savings stage

\[ U^i(a, h_0, \chi; \psi) = \max_{c, a'} u(c, l_1, h_0, \chi_i) \]

\[ + \beta \mathbb{E} \left\{ \max_{p, a' \geq a_0} \pi_b(p; \psi') D^i(a' - p, h_1, \chi'; \psi') \right\} \]

\[ + \left[ 1 - \pi_b(p; \psi') \right] \max_{j \in I} \left\{ D^j(a', h_0, \chi'; \psi') \right\} \]

\[ a + b = c + \rho^i(\psi) + \frac{a'}{1 + r} \]

\[ a' \geq a_0. \]
Here, $U^i(a, h_0, \chi; \psi)$ is the value of being unemployed in location $i$ to a renter ($h_0$) with assets $a$ and an $I \times 1$ vector of preference for locations $\chi \equiv \{\chi_i\}_{i \in I}$. The household chooses current consumption ($c$) and savings ($a'$), subject to the budget constraint that we present and discuss below, and obtains an instantaneous utility of $u(c, l_1, h_0, \chi_i)$ and goes to the next period. At the beginning of the next period, housing markets open. Since he is a renter, he has the option of purchasing a house. He chooses the purchasing price $p$, subject to the down payment constraint $a' \geq \alpha p$. For that price, his expected payoff is

$$\pi_b(p; \psi')D^i(a' - p, h_1, \chi'; \psi') + \left[1 - \pi_b(p; \psi')\right] \max_{j \in I} \left\{D^j(a', h_0, \chi'; \psi')\right\}$$

(20)

The first term reflects the fact that he finds a seller with probability $\pi_b(p; \psi')$ and obtains the ownership of the house upon paying the transaction price. In that case, his assets are given by $a' - p$. He enters the migration stage as a homeowner and is not allowed to move. After the migration stage comes the job search stage. He looks for a job in his current location $i$. This delivers an expected payoff of $D^i(a' - p, h_1, \chi'; \psi')$. The value function $D$ denotes the value of searching for a job in location $i$ and will be defined below. The second term in equation (20) reflects the fact that the household does not find a seller with complementary probability. In that case, he is still a renter and can choose to move.

We now turn to the budget constraint facing the unemployed renter. His resources for the period are given by his assets and the unemployment benefit he collects. He uses these to finance current consumption $c$, rent $\rho^i(\psi)$, and savings. He can borrow and save at interest rate $r$, subject to the borrowing constraint that $a' \geq a_0$. 

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Unemployed Homeowners:  Equation (21) shows the problem of an unemployed homeowner:

\[ U^i(a, h_1, \chi; \psi) = \max_{c, a'} u(c, l_1, h_1, \chi_i) \]

\[ + \beta \mathbb{E} \left\{ \max_p \pi_s(p; \psi') \max_{j \in I} \{ D^j(a' + p, h_0, \chi'; \psi') \} + [1 - \pi_s(p; \psi')] D^i(a', h_1, \chi'; \psi') \right\} \]

\[ a + b = c + \frac{a'}{1 + r} \]

\[ a' \geq a_1. \]

Here, \( U^i(a, h_1, \chi; \psi) \) is the value of being unemployed in location \( i \) to a homeowner with assets \( a \) and preference for locations \( \chi \). The homeowner chooses current consumption \( (c) \) and savings \( (a') \), subject to the budget constraint, and obtains an instantaneous utility of \( u(c, l_1, h_1, \chi_i) \) and goes to the next period. At the beginning of the next period, housing markets open. The unemployed homeowner has the option of selling the house. He decides the selling price \( p \) that then determines the probability of finding a buyer. For that price, the expected payoff is given by:

\[ \max_p \pi_s(p; \psi') \max_{j \in I} \{ D^j(a' + p, h_0, \chi'; \psi') \} + [1 - \pi_s(p; \psi')] D^i(a', h_1, \chi'; \psi'). \] (22)

The first term reflects the fact that the household transfers the ownership of the house to a realtor with probability \( \pi_s(p; \psi') \) and receives the payment \( p \). In that case, the household’s assets are given by \( a' + p \). Consequently, the household enters the migration stage as a renter.
and decides whether to move to another location or remain in the current location. Similar to the renter’s problem, \( \max_{j \in I} D^j(a' + p, h_0, \chi'; \psi') \) measures the value of looking for a job on another location. The second term in equation (22) reflects the fact that the household does not find a buyer with complementary probability. In that case, as a homeowner, the household is not allowed to migrate. As a consequence, he searches for an employer in the current location \( i \) and obtains a value of \( D^i(a', h_1, \chi'; \psi'). \)\(^{32}\)

Equation (22) highlights the option value of migration. By selling the house, the homeowner obtains this option value. Clearly, the more the household wants to migrate, the sooner he would like to sell the house. As a result, differences between labor markets and a homeowner’s preference for his current location affect the price-posting decision.

**Employed Renters:** We now turn to the problem of employed households. We start by describing the decision problem of an employed renter. Equation 23 shows the Bellman

\[^{32}\text{It is worth noting that we do not allow homeowners to foreclose on their homes. In other words, homeowners do not have the option to simply walk away from their homes and get their mortgage debt discharged. However, we allow households to sell their houses at any price and then move even if their assets are not enough to cover the debt on the house. This can be interpreted as the foreclosure option in recourse states in the United States. If exercised, this option leaves the household with negative assets after the move. As a consequence, the household ends up living as a renter for a period of time until he accumulates enough down payment. We would like to emphasize that in the United States a foreclosure results in a substantial worsening of the credit score and makes it almost impossible to get a mortgage for another home for several years, essentially making the household a renter for a period of time. Although the mechanics are somewhat different, we believe that our model captures the relevant tradeoff for homeowners, and that an additional option of foreclosure would not alter their mobility behavior.}\]
equation for an employed renter in location $i$:

$$W^i(w, a, h_0, \chi; \psi) = \max_{c,a'} u(c, l_0, h_0, \chi_i)$$

$$+ \beta \mathbb{E} \left\{ (1 - \delta) \left( \max_{a' \geq \alpha p} \pi_b(p; \psi') W^i(a' - p, h_1, \chi'; \psi') \right. \right.$$ 

$$+ \left[1 - \pi_b(p; \psi') \right] W^i(a', h_0, \chi'; \psi') \right\}$$

$$+ \delta \left( \max_{a' \geq \alpha p} \pi_b(p; \psi') D^i(a' - p, h_1, \chi'; \psi') \right.$$

$$+ \left[1 - \pi_b(p; \psi') \right] \max_{j \in I} \{D^j(a' - p, h_1, \chi'; \psi')\} \right\}$$

$$a + w = c + \rho(\psi) + \frac{a'}{1 + r}$$

$$a' \geq a_0.$$ 

Here, $W^i(w, a, h_0, \chi; \psi)$ is the value of being employed at wage $w$ in location $i$ to a renter $(h_0)$ with assets $a$ and preference for locations $\chi$. The household chooses current consumption $(c)$ and savings $(a')$, subject to the budget constraint, and obtains an instantaneous utility of $u(c, l_0, h_0, \chi_i)$ and goes to the next period. At the beginning of the next period, job destruction shock $\delta$ and productivity shocks are realized. The second line in equation (23) captures the event that the employed renter keeps his job. The household has the option of buying a house in the housing market. The renter decides the buying price $p$ (subject to the down payment constraint) that then determines the probability of finding a seller. For that price, the expected payoff is given by:

$$\pi_b(p; \psi') W^i(a' - p, h_1, \chi'; \psi') + [1 - \pi_b(p; \psi')] W^i(a', h_0, \chi'; \psi').$$  

(24)
Here, the first term measures the payoff associated with buying the house: upon finding a seller, the buyer pays the house price and becomes an employed renter. With complementary probability \( 1 - \pi_0(p; \psi') \), he does not find a seller and remains an employed renter. Being employed, he is not allowed to migrate or look for another job and skips these two stages to obtain a value of \( W^i(a' - p, h_0, \chi'; \psi') \).

The last two lines in equation (24) capture the event that the renter loses his job and becomes unemployed. For this household, the rest of the problem looks very similar to that of an unemployed renter: the renter decides whether to purchase a house or not. In the case of a successful purchase, he searches for a job locally. In the other case, he decides whether to move or not and then looks for a job. The budget constraint facing an employed renter is very similar to the one facing an unemployed renter, the difference being the labor income \( w \) instead of the unemployment benefits \( b \).
Employed Homeowners: Equation (25) shows the Bellman equation for an employed owner in location $i$:

$$W^i(w, a, h_1, \chi; \psi) = \max_{c, a'} u(c, l_0, h_1, \chi_i)$$

$$+ \beta \mathbb{E} \left\{ (1 - \delta) \left( \max_{p} \pi_s(p; \psi') W^i(a' + p, h_0, \chi'; \psi') ight) 
+ [1 - \pi_s(p; \psi')] W^i(a', h_1, \chi'; \psi') \right\}$$

$$+ \delta \left( \max_{p} \pi_s(p; \psi') \max_{j \in I} \{ D^j(a' + p, h_0, \chi'; \psi') \} 
+ [1 - \pi_s(p; \psi')] D^i(a', h_1, \chi'; \psi') \right) \right\}$$

$$a + w = c + \frac{a'}{1 + r}$$

$$a' \geq a_1$$

Here, $W^i(w, a, h_1, \chi; \psi)$ is the value of being employed at wage $w$ in location $i$ to a homeowner with assets $a$ and preference for locations $\chi$. The household chooses current consumption $(c)$ and savings $(a')$, subject to the budget constraint, and obtains an instantaneous utility of $u(c, l_0, h_1, \chi_i)$ and goes to the next period. At the beginning of the next period, job destruction and productivity shocks are realized. The second line in equation (25) captures the event that the homeowner keeps his job. He has the option of selling the house in the housing market. Selling delivers a payoff of $W^i(a' + p, h_0, \chi'; \psi')$ and not selling delivers a payoff of $W^i(a', h_1, \chi'; \psi')$. If the homeowner becomes unemployed, by setting a selling price $p$, he may try to sell the house and get the option value of migration $(\max_{j \in I} \{ D^j(a' + p, h_0, \chi'; \psi') \})$ or not sell it and get a payoff of $D^i(a', h_1, \chi'; \psi')$. 

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9.3.2 The Job Search Problem

So far, we have described the problem of employed and unemployed homeowners and renters at the consumption and savings stage as well as in the housing market. Here, we describe the search problem of households in the labor market. Recall that, by assumption, only unemployed households are allowed to search for jobs and that job search is local: households in a given location can apply only for vacancies in the same location.

Compared to a random-matching technology, where there is a single market tightness in the labor market $\theta(\psi)$, there is a continuum of wages and corresponding market tightnesses in this model, due to the directed nature of search. Households decide in which submarket (at what wage) to look for jobs. Submarkets are indexed by the fixed wage $w$, and the market tightness in this submarket is given by $\theta^i_l (w; \psi)$. Correspondingly, $\pi_l [\theta^i_l (w; \psi)]$ denotes the probability of a worker’s finding a job as a function of the applied wage $w$.

The value of searching in the local labor market for a household with assets $a$ and housing status $h$ is given by

$$D^i (a, h, \chi; \psi)$$

$$= \max_w \pi_l [\theta^i_l (w; \psi)] W^i (w, a, h, \chi; \psi) + \left(1 - \pi_l [\theta^i_l (w; \psi)] \right) U^i (a, h, \chi; \psi) .$$

Policy Functions: We now introduce the notation for optimal policy rules, since they will be used in the definition of a recursive equilibrium. The optimal rule for the savings decision of employed and unemployed households is denoted by $g^i_W$ and $g^i_U$, respectively. The optimal house-buying price is denoted by $p^i_b$, and the optimal house-selling price is denoted by $p^i_s$. The optimal migration decision is denoted by $m^i$. Finally, we denote the
optimal solution to the job search problem in equation (26) by $w^i$.

9.4 The Problem of the Firm

We now turn to firms in the labor market. Firms post vacancies to hire workers. Each vacancy lasts for one period. Recall that the job search is directed, so that when a firm decides to post a vacancy, it also decides in which submarket to post it. Our contract space allows only for fixed-wage contracts; therefore, vacancies are indexed by the offered wages $w$. The value to the firm of being matched with a worker and paying wage $w$ in location $i \in I$ can be written as:

$$J^i(w; \psi) = z_i - w + \frac{1 - \delta}{1 + r} E J^i(w; \psi').$$  \hspace{1cm} (27)

Posting a vacancy requires the payment of cost $k$. The value of creating a vacancy in location $k$ with wage $w$ is given by

$$V^i(w; \psi) = -k + q_l \left[ \theta^i_l(w; \psi) \right] J^i(w; \psi),$$ \hspace{1cm} (28)

where $q_l$ denotes the probability of finding a worker at wage $w$ and is a function of the labor market tightness $\theta^i_l(w; \psi)$. When the value of creating one vacancy at wage $w$ is strictly positive, the firm finds it optimal to create infinite vacancies. When it is strictly negative, no vacancies are created in submarket $w$. When the value is zero, then the firm’s profit is independent of the number of vacancies it creates in submarket $w$.

We assume free entry of firms. Therefore, in any submarket visited by a positive measure
of workers, the following must hold:

$$k \geq q_l \left[ \theta^i_l (w; \psi) \right] J^i (w; \psi) ,$$

(29)

with complementary slackness. That is, equation (29) must hold with equality if \( \theta^i_l (w; \psi) > 0 \). When we focus on block-recursive equilibrium, we will focus on equilibria that have a positive number of entrants every period.

### 9.5 The Problem of Housing Market Intermediaries

Our work borrows from the insights of Menzio and Shi (2010a) and extends the notion of block recursivity to the housing market. In what follows, we will describe the structure of the housing market that gives rise to the existence of such an equilibrium. As we will see in the next section, this equilibrium requires a combination of directed search and free-entry conditions in every market. The introduction of the housing market intermediaries makes the existence possible. We have three types of firms in the housing market: real estate managers (REM), leasing companies, and construction companies.

REMs with a vacant house try to sell it to buyers. They get a payoff of \( p \) when they succeed in selling a house at price \( p \) but get no flow payoff from having vacant houses. Therefore, the value of holding a vacant house in location \( i \in I \) to a real estate manager is

$$R^i (\psi) = \max_p q_b \left[ \theta^i_b (p; \psi) \right] p + \left( 1 - q_b \left[ \theta^i_b (p; \psi) \right] \right) \frac{1}{1 + r} \mathbb{E} R^i (\psi') ,$$

(30)

where \( \theta^i_b (p; \psi) \) is the market tightness for the housing submarket with price \( p \). The subscript \( b \) indicates that this is the side of the housing market where households are buyers. Equation
(30) holds that REMs choose the price $p$ at which they are willing to sell the house and are successful in doing so with probability $q_b \left[ \theta_b^i (p; \psi) \right]$. They cannot find a buyer with complementary probability and the house remains for one period.

We now turn to the other side of the housing market. In order to buy houses from sellers in the housing market, REMs post vacancies by paying a cost $\kappa$. As in the other markets, the search is directed so that when REMs decide to post vacancies, they also decide the price at which they are willing to buy. There is full commitment to the posted price, so that whenever a REM meets a homeowner, the housing unit is transferred to the REM at price $p$. The value of posting a vacancy for a REM in location $i \in I$ at price $p$ is given by

$$Q^i (p; \psi) = -\kappa + q_s \left[ \theta^i_s (p; \psi) \right] \left[ R^i (\psi) - p \right].$$  

(31)

We assume free entry of REMs. Therefore, a free-entry condition similar to (29) holds for all the submarkets in the selling market that are visited by a positive measure of homeowners. This is given by

$$\kappa \geq q_s \left[ \theta^i_s (p; \psi) \right] \left[ R^i (\psi) - p \right],$$  

(32)

with equation (32) holding with equality whenever $\theta^i_s (p; \psi) > 0$.

Leasing companies operate in a competitive rental market. The rental contract is for one period. At the end of every period, a constant fraction $\gamma$ of rental houses depreciates. Depreciation is discrete: that is, these rental houses are completely destructed. Leasing companies get the rental rate, $\rho^i (\psi)$, as a flow payoff, until the unit disappears. Thus, the value of holding a rental house to leasing companies is given by

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\[ L^i(\psi) = \rho^i(\psi) + \frac{1 - \gamma}{1 + r} \mathbb{E}L^i(\psi') \, , \] (33)

Depreciation is important for ensuring that in every period new houses are built, which in turn is important to making the free-entry conditions hold with equality. We elaborate on this issue when we discuss the existence of a block-recursive equilibrium.

Finally, we turn to construction companies. Construction companies can build a new house immediately at cost \( \mu_i \). They then have the choice of becoming REMs and trying to sell these units to renters or of becoming leasing companies and renting out the house. As long as the value of holding a house to a REM exceeds the cost of constructing a new one, there will be new construction. This setup introduces two additional free-entry conditions:

\[ \mu_i \geq R^i(\psi) \] (34)

\[ \mu_i \geq L^i(\psi) \] (35)

9.6 Equilibrium

We now define a recursive equilibrium for this economy. We denote the set of housing service types as \( \mathcal{H} = \{0, 1\} \) and the set of locations as \( I = \{1, 2, \ldots, \bar{I}\} \). The set of local productivity shocks is given by \( Z = [\underline{z}, \overline{z}] \). Define \( \mathcal{W} = [b, z_N] \) to be the set of possible wages and \( \mathcal{A} = [\underline{a}, \overline{a}] \) to be the set of possible assets.\(^{33}\) Let \( \Xi \) denote the set of preference shocks.

Finally, let \( \Psi \) denote the possible realizations of the aggregate state.

\(^{33}\)It is easy to prove that there are endogenous bounds on the set of possible wages that will be offered and thus on the set of assets that will be realized in equilibrium. The assumption of bounded sets is, in that sense, not an assumption but a result.
Definition 5. A recursive equilibrium comprises

▷ a set of value functions for households:

\[ \left\{ W^i : \mathcal{W} \times \mathcal{A} \times \mathcal{H} \times \Xi \times \Psi \to \mathbb{R} \right\}_{i \in I}, \]

\[ \left\{ U^i : \mathcal{A} \times \mathcal{H} \times \Xi \times \Psi \to \mathbb{R} \right\}_{i \in I}, \quad \text{and} \]

\[ \left\{ D^i : \mathcal{A} \times \mathcal{H} \times \Xi \times \Psi \to \mathbb{R} \right\}_{i \in I}. \]

▷ a set of policy functions for households:

\[ \left\{ g^i_W : \mathcal{W} \times \mathcal{A} \times \mathcal{H} \times \Xi \times \Psi \to \mathbb{R}, \quad g^i_U : \mathcal{A} \times \mathcal{H} \times \Xi \times \Psi \to \mathbb{R} \right\}_{i \in I}, \]

\[ \left\{ p^i_b : \mathcal{W} \times \mathcal{A} \times \mathcal{H} \times \Xi \times \Psi \to \mathbb{R}^+, \quad p^i_s : \mathcal{W} \times \mathcal{A} \times \mathcal{H} \times \Xi \times \Psi \to \mathbb{R}^+ \right\}_{i \in I}, \]

\[ \left\{ m^i : \mathcal{A} \times \Xi \times \Psi \to \mathbb{R}^+ \right\}_{i \in I}, \quad \text{and} \]

\[ \left\{ w^i : \mathcal{A} \times \mathcal{H} \times \Xi \times \Psi \to \mathbb{R}^+ \right\}_{i \in I}. \]

▷ value functions for firms:

\[ \left\{ J^i : \mathcal{W} \times \Psi \to \mathbb{R} \right\}_{i \in I}. \]

▷ value functions for intermediaries in the housing market:

\[ \left\{ R^i : \Psi \to \mathbb{R}, \quad L^i : \Psi \to \mathbb{R} \right\}_{i \in I}. \]
market tightness functions in the labor market:

\[ \{ \theta^i_l : \mathcal{W} \times \Psi \to \mathbb{R}_+ \}_{i \in I} \].

market tightness functions in the housing market:

\[ \{ \theta^i_s : \mathbb{R}_+ \times \Psi \to \mathbb{R}_+, \theta^i_b : \mathbb{R}_+ \times \Psi \to \mathbb{R}_+ \}_{i \in I} \].

a transition probability function for the aggregate state of the economy \( \Phi : \Psi \times \Psi \to [0,1] \); such that

1. **Households maximize:** Given the market tightness functions, the value functions solve (19), (21), (23), (25), and (26), and \( \{ g^i_W \}_{i \in I}, \{ g^i_U \}_{i \in I}, \{ p^i_b \}_{i \in I}, \{ p^i_s \}_{i \in I}, \{ m^i \}_{i \in I} \) and \( \{ w^i \}_{i \in I} \) are the associated policy functions.

2. **Firms and housing market intermediaries maximize:** \( \{ J^i \}_{i \in I} \) solves 27, and \( \{ R^i \}_{i \in I} \) and \( \{ L^i \}_{i \in I} \) satisfy (30) and (33), respectively.

3. **Free entry of firms:** Given the value function of firms \( \{ J^i \}_{i \in I} \), the market tightness function \( \{ \theta^i_l \}_{i \in I} \) satisfies (29).

4. **Free entry of real estate managers:** Given the value function of housing intermediaries, (32) holds.

5. **Free entry of construction companies:** (34) and (35) are satisfied.

6. **Law of motion for the aggregate state space:** \( \Phi \) is derived from the policy functions of households and the transition function of the productivity shocks.
9.7 Existence of a Block-Recursive Equilibrium

Solving a recursive equilibrium outside of the steady state requires solving functional equations in which the functions depend on the entire distribution of workers across locations, assets, employment states, housing tenure, and preference shocks. This solution requires keeping track of an infinite-dimensional object. In general, this feature makes the problem difficult to solve, even numerically. In the presence of search frictions, this class of models becomes even more complex. To address this difficulty, we utilize the notion of block recursivity. We now define this property and show the existence of an equilibrium with that property. We then elaborate on the usefulness of this result and discuss the structure of the market that makes it possible.

**Definition 6.** A block-recursive equilibrium (BRE) is a recursive equilibrium such that the value functions, policy functions, and market tightness functions depend on the aggregate state of the economy $\psi$, only through the stochastic shocks $\{z_i\}_{i \in I}$, and not through any endogenous distributions generated within the economy ($\{\Gamma_i\}_{i \in I}$, or $\{n_i\}_{i \in I}$); and free-entry conditions (29), (32), (34), and (35) are satisfied with equality.

**Proposition 2.** There exists a block-recursive equilibrium.

*Proof.* Proof. See appendix F.

Let us now elaborate on the usefulness of proposition 2. In general, there is no easy way to compute an equilibrium of this model because of the high dimensionality of the state space. A commonly used approach in the literature is to approximate the distribution with several moments and make a conjecture about a law of motion for them. One can iterate on
this conjecture to make it consistent with the policy rule of the households.\footnote{More precisely, one solves a household’s decision problem, given this law of motion, to obtain optimal policy rules. By simulating data from the model with these policy rules, one can obtain the implied law of motion for aggregate variables and compare it to the conjectured law of motion. The conjecture is revised until the procedure converges.} Note that this procedure already adds a large number of (continuous) state variables: we need to add at least homeownership and unemployment rates, fraction of population across locations, mean assets, and mean wages. Typically, having a good description of the evolution of aggregate variables requires second-order moments. This approach renders our model impossible to compute.\footnote{Solving only the household problem, taking as given the market tightness functions, takes on average 15 hours on a cluster with 20 cores.}

Proposition 2 asserts that there exists a block-recursive equilibrium. Moreover its proof reveals that it is possible to compute the market tightness functions in the housing and labor markets \textit{without} solving the household’s decision problem. With those, it is straightforward to solve the decision problem of the households. This makes it possible to solve the model in two steps: First, solve for the market tightness functions using the free-entry conditions. Second, solve the household’s problem taking as given the market tightness functions. Further details regarding the computation of the model, see Appendix G.

It is important to note that the endogenous distribution of households matters for the evolution of the economy: migration decisions, job search decisions, and house-buying and -selling decisions all depend on individual characteristics. Therefore, the response of the aggregate variables (for example unemployment rate, homeownership rate, etc) to shocks will depend crucially on the distribution of households (across assets, wages, etc) at the time the shock hits the economy. Block-recursive equilibrium is an equilibrium in which prices do not depend on endogenous distributions generated in the economy, but the evolution of
important endogenous variables do.

As stressed in Menzio and Shi (2010a), the directed nature of the search technology is important for Proposition 2. The reason is the following: if search is random (but there is still price posting), then a firm needs to forecast what type of worker will apply and show up. The necessity arises because the type of worker affects the probability that the job will be accepted. To compute expectations appropriately, the firm needs to know the entire distribution of households. A similar problem arises in a housing market with random search. Real estate managers in the housing market would need to forecast what type of buyer will show up, as this determines the willingness to pay for the house. This, again, requires knowledge of the entire distribution.

Free entry of firms is also important as it pins down the relationship between the offered wage and the probability of finding a worker—hence the corresponding tightness of the submarket. The introduction of housing market intermediaries and construction companies gives rise to three free-entry conditions, as we have shown above. Free entry is critical for the existence of block-recursive equilibrium.\footnote{An alternative structure to ours could be to have directed search in the housing market but have households trade among themselves. That is, sellers post houses, and buyers look for houses. Although this is perhaps a more realistic setup, one needs free-entry conditions to pin down market tightnesses in the housing market.}

10 Calibration

We now turn to the calibration of the model. We calibrate the model to match a number of targets related to the labor and housing markets, mobility patterns, and wealth distribution before the housing bust in 2007. Before addressing the Great Recession, we evaluate
the model's performance along a number of untargeted dimensions such as business cycle statistics, cyclicality of migration rates, and correlation between net flow rates and local unemployment rates. We then use the model to study the Great Recession.

10.1 Functional Forms

Let us introduce functional forms for the utility function and the matching probabilities. The utility function takes the following form,

\[
    u(c, l, h, \chi) = \left( c + \lambda (1 - l) + \phi_h \right)^{1 - \sigma} + \chi,
\]

where \( \phi_h \) is the consumption services from housing type \( h \) and \( \lambda \) is the value of home production and leisure. If \( l = 1 \), the household is currently employed and \( \lambda (1 - l) = 0 \). If \( l = 0 \), the household is currently unemployed and gets a flow consumption of \( \lambda \) from home production. Note that because home production is not tradable, it directly enters the utility function as a perfect substitute for the consumption good.

Following Menzio and Shi (2011) and Schaal (2012), we pick the contact rate functions with constant elasticity of substitution

\[
    p(\theta) = \theta (1 + \theta^\gamma)^{-1/\gamma}, \quad q(\theta) = (1 + \theta)^{-1/\gamma}
\]

for both the labor and housing markets.\(^{37}\) \( \gamma_l, \gamma_b, \) and \( \gamma_s \) denote the matching function parameters for the labor market and for the buying and selling sides of the house-buying market, respectively. We assume that \( \gamma_b = \gamma_s \).

\(^{37}\)Apart from providing a good fit to the data, a constant-returns-to-scale matching function is needed for the existence of a block-recursive equilibrium.
10.2 Stochastic Process for Labor Productivity

We need to calibrate the stochastic processes for labor productivity, that is, to calibrate $Z$ and its transition function $\Upsilon_Z$. We measure labor productivity as output per worker and estimate the following specification to obtain the persistence and variance of local labor productivity shocks at annual frequency:

$$\log z_{i,t} = \alpha + \rho \log z_{i,t-1} + \epsilon_{i,t}.$$ 

Since our data are annual, we convert point estimates to monthly numbers. Results are reported in Table 10. We discretize the process for local labor productivity using the Rouwenhorst method with four grid points.\(^{38}\)

10.3 Calibration Strategy

Calibration proceeds in two steps. In the first step, we exogenously calibrate parameters that have direct counterparts in the data or can be taken from previous studies because they are not model dependent. The second step follows a simulated method of moments.

**Parameters Calibrated a Priori:** A period in the model corresponds to a month. We set the monthly interest rate $r$ to match an annual interest rate of 3 percent.\(^{39}\) The risk-aversion coefficient in the utility function $\sigma$ is set to 2. The down payment requirement for buying a home is set to 10 percent. This requirement is lower than the typical 20 percent

\(^{38}\)A more common alternative in the literature is the Tauchen method. A drawback of this method is that it requires many grid points to approximate well a highly persistent process. Computational concerns limit our choice of the number of grid points. The Rouwenhorst method, on the other hand, performs a better job with fewer grid points. Using simulated data, we verify that four grid points suffice to provide a good fit.

\(^{39}\)\(r = (1 + 3\%)^{1/12} - 1 \approx 0.25\%\).
used in most of the literature on housing but is consistent with the financial developments in the housing market before the housing bust in 2007. Average replacement rate in the unemployment insurance system is around 40 percent. Consistent with this, \( b \) is set to 0.4.

The monthly job destruction rate \( \delta \) is set to 3.4 percent, as reported in Shimer (2005).\(^{40}\) Table 11 summarizes the parameters of the model. The top panel presents parameters that are calibrated outside the model, and the bottom panel presents those that are calibrated within the model.

**Parameters Calibrated with the Simulated Method of Moments:** Parameters in the bottom panel of Table 11 are estimated by the simulated method of moments. The parameters are chosen to minimize the distance between the model-generated statistics and the targets in the data. The distance is defined as the percentage deviation from the target and uses the identity matrix as the weighting matrix. We now explain the targeted moments in the data in detail.

We start by describing moments related to the housing market. We target a homeownership rate of 69 percent, and an average time to sell of 3.5 months.\(^{41}\) Vacancies posted by homeowners to sell a house last for one period in the model. We define the model counterpart of time to sell as the inverse of selling probability \( 1/\pi_s \). To calibrate the elasticity of the matching function, we need a moment that relates the posted price to the time to sell. To that end, we target the findings of Genesove and Mayer (1997), which show that

\(^{40}\)This is constructed in Shimer (2005) using data on employment, short-term unemployment, and the hiring rate. The number reported is the average monthly separation rate over the period 1951 to 2003.

\(^{41}\)This is the homeownership rate in the United States right before the onset of the housing bust. See [http://www.census.gov/hhes/www/housing/hvs/charts/files/fig05.pdf](http://www.census.gov/hhes/www/housing/hvs/charts/files/fig05.pdf). Average time to sell is taken from the National Association of Realtors website. Different sources report different numbers that range between 2.5 and 5.5 months at times with “good” housing markets.
homeowners with 100 percent leverage post prices about 4 percent higher than homeowners with 80 percent leverage. They report that the corresponding time to sell is 15 percent lower for the highly leveraged homeowners.

We now elaborate further on this part of the calibration. There are two parameters on search in the housing market that need to be calibrated: vacancy posting cost $\kappa$ of REMs and the “elasticity” parameters in the matching function $\gamma_s = \gamma_b$. The average time to sell is intimately linked to $\kappa$, as changes in this parameter shift the entire market tightness functions (and thus the relationship between selling price and the probability of trade). The elasticity parameter, however, governs how the probability of trade is affected by a change in selling price. The decision problem of the household provides a mapping between asset position and the optimal selling price. By taking the composition of this decision rule with the market tightness function that maps the price to the time to sell, we can construct the model counterpart of the relationship between leverage and time to sell. This moment depends tightly on the elasticity parameter and is therefore used to calibrate it.

How can the model generate a negative relationship between assets and time to sell? There are two forces in the model. Households with lower assets have a higher propensity to move for job-related reasons. This is because their marginal utility of consumption is higher compared to households with more liquid wealth. Households with fewer assets (and thus more leverage), however, find it harder to afford a new house after moving and end up renting for many periods because of the financial friction in the model—the down payment constraint. Because households obtain a higher utility from owning (also a calibrated parameter), highly leveraged households have a motive to post higher selling prices (and sell slower) than households with lower leverage. The relationship between leverage and
time to sell is a result of this trade-off. It turns out that the model does generate the right relationship quantitatively.

This strategy is analogous to the standard one in the search literature that is used to calibrate the vacancy posting cost and matching function parameter. For example, Shimer (2005) uses average job finding probability and the correlation between the job finding rate and market tightness. The former is (mostly) informative about the average job finding rate, and the latter is informative about the correlation. The average time to sell is analogous to the job finding probability, and the elasticity of time to sell with respect to leverage is analogous to the elasticity of the job finding probability with respect to market tightness.

Finally, we target the ratio of average house prices to average monthly earnings in the model. To determine the empirical value of this moment, we compute the ratio of average house price to average monthly wages for each year over between 2001 and 2005. We then average this time series to obtain an average of 48.

Turning to the labor market dimension of the model, we target an average job finding rate of 45 percent and a correlation at the quarterly frequency between the (log) job finding rate and the market tightness of 0.94. Both targets are the same as in Shimer (2005). In the model presented above, there are multiple submarkets in the labor market at any time and thus multiple job finding rates at any point in time. Unlike in Shimer (2005), the elasticity cannot be calibrated before solving the model: we need to solve and simulate the model to obtain the average job finding probabilities across different submarkets, weighted by the number of workers that apply there. The resulting series from the model is monthly. We obtain quarterly series by taking the average over three months. The quarterly time series

\footnote{Alternatively, one can use the change in the unemployment rate in the model to infer average job finding probability.}
for the (log) job finding probabilities and (log) market tightnesses are then filtered with an Hodrick–Prescott filter using a scaling parameter of 1600. The model counterpart of the correlation is computed using the detrended series.

The model also has predictions about mobility rates. We target two mobility-related moments: average gross mobility and average net mobility in the United States. Gross mobility is defined as the average of population inflow and outflow rates: that is, 
\[
grossmobility = \frac{\sum_i \sum_t |inflow_{i,t} + outflow_{i,t}|}{2NT},
\]
where \(N\) is the number of MSAs for which we have data on population flows and \(T\) is the number of years our data span. Net mobility is defined as the average of absolute values of population net flows: that is, it is given by
\[
netmobility = \frac{\sum_i \sum_t |inflow_{i,t} - outflow_{i,t}|}{NT}.
\]
Empirical values for gross and net migration are computed from the IRS data. We use data for the period 2004–2007 to exclude the recession period. We find an average gross migration rate of 4.3 percent and an average net migration rate of 0.8 percent.

The key parameters that help us match the net and gross migration rates are the persistence and variance of preference shocks. In the model, net migration occurs because of differences in labor productivity across the two locations: households tend to relocate themselves to places with better labor productivity because it is easier to find jobs and also wages are higher. Unemployed households would like to look for a job in the location with higher labor productivity. Absent any other motive, the model-generated net mobility is the same as gross mobility. Preference shocks make people move for non-labor-market-related reasons and make them move in both directions at the same time. That is, we observe that populations that lose workers also attract new workers, thus breaking the relationship between net migration and gross migration. If the persistence of preference shocks gets larger, house-
holds do not respond to local labor market differences as much, and the net migration rate decreases. Yet, gross mobility is large because households move whenever their preferences so dictate. This intuitive discussion suggests that the persistence of preference shocks helps us match the difference between gross and net migration rates. Increasing the variance of preference shocks, however, increases the gross migration rate as households are hit by larger preference shocks. By choosing the persistence and variance of preference shocks, we can calibrate the model to match the gross and net migration rates exactly.

We target a median leverage of 67 percent, which is computed from the 2004 wave of the Survey of Consumer Finances. Leverage in the model is computed as the ratio of household debt to the average house selling-price in a household location. Table 11 shows the resulting parameter values, and Table 12 summarizes the targets and the fit of the model with respect to the targeted moments.

10.4 The Model’s Fit on Nontargeted Moments

Before using the model to address the Great Recession, we evaluate the model’s performance along a number of untargeted dimensions of the data. Our model has predictions on how much the population of a location changes following a local labor market shock. We therefore compare three quantitative predictions of our model to the data: standard deviation of gross and net flows, the cyclicity of migration, and the correlation between local labor market conditions and local population flows.
10.4.1 Volatility of Migration

Table 13 reports the volatility of aggregate gross and net migration rates computed from the model and from the data. While the volatility of migration rates is higher in the model than in the data, we find that, as in the data, gross migration is more volatile than net migration. Because only the unemployed people make mobility decisions in our model, migration rates tend to move together with local and aggregate unemployment. As we discussed before, migration is a result of the trade-off between idiosyncratic tastes and differences in local productivity. Idiosyncratic shocks in the calibrated model are quite persistent and prevent many people from moving in response to differences across the two labor markets. Consequently, the response of net migration to differences in productivity across locations is dampened. However, gross migration is greatly affected by aggregate unemployment. As unemployment goes up, more people move to follow their idiosyncratic taste for location. As a result, gross migration is more volatile than net migration.

10.4.2 Local Labor Market Conditions and Migration

Table 14 shows the regression coefficient of outflow rates on relative productivity. Relative productivity is defined as the deviation of local productivity from aggregate productivity \((\log(z_t) - \log(z_{i,t}))\) in a year, and is defined such that a positive value indicates that the productivity in the location is lower than aggregate productivity in the economy. The model is able to replicate the negative relationship between outflows and relative productivity, suggesting that in the benchmark model without housing-market-related frictions, households...
move out of low-productivity locations.

10.4.3 Cyclicality of Migration

Finally, we analyze the cyclicality of gross migration in our estimated model. In particular, as we will show in the next section, our model predicts a rise in migration rates during the Great Recession (absent frictions arising in the housing market). In what follows, we will show that this does not happen in a typical recession in our model and is a consequence of heterogeneous productivity shocks specific to the Great Recession. In fact, the model delivers, consistent with the data, a procyclical gross migration rate.

Table 15 reports the regression coefficient of the log of gross migration rate on log unemployment. We use the numbers reported in Davis et al. (2010) on MSA-level gross migration rates. We regress the log of this variable on aggregate unemployment and report the coefficient. As Table 15 shows, our model is able to generate a procyclical gross migration rate.

There are two main forces in the model that affect the cyclicality of gross migration. On the one hand, there is a composition effect: in our model, only the unemployed workers are allowed to migrate. Since in a recession there are more unemployed households, migration tends to increase during recessions. On the other hand, households care less about preference shocks during a recession because of the functional form of the utility function. Preference shocks enter the utility function in a separable fashion, implying that, for a given level of preference shock, the marginal benefit of migration is constant over time. However, moving is costly and entails a wealth loss because it involves selling the house, and selling takes place in a frictional housing market. Hence, there is a trade-off between moving for preference-
related reasons and avoiding the loss. Since the marginal utility of consumption is higher in a recession, the migration rate tends to be procyclical.\textsuperscript{44} It turns out that the income effect dominates the composition effect, resulting in a procyclical gross migration rate that is consistent with the data.

11 Housing Bust and the Great Recession

Using the calibrated model, we now quantify the effect of the housing bust on the dispersion of unemployment rates across MSAs during the recent recession. To study the effects of the housing bust through our two-location framework, we need to group the MSAs in the United States into two categories. We choose the groups based on the size of the housing bust: location $A$ contains all the MSAs in our dataset where house prices declined by less than 35 percent, and location $B$ contains the remaining MSAs.\textsuperscript{45} Out of the 341 MSAs for which we have data on house prices, 250 are assigned to location $A$. According to our categorization, house prices declined by 19.6 percent in location $A$ and 46.8 percent in location $B$. We engineer this decline in the model as the consequence of a one-time, unanticipated, and permanent decline in housing construction costs $\{\mu_i\}_{i=1,2}$\textsuperscript{46}

To isolate the effect of the housing bust on geographical reallocation during the Great Recession, we run the following two experiments. In the first simulation, which we label the factual simulation, we feed into the model the exact labor productivities observed in the data.

\textsuperscript{44}This argument is analogous to the ones used in the health literature to explain the rise in health expenditures over time and the differences in health expenditures between high- and low-income households. For example, see Hall and Jones (2007).

\textsuperscript{45}The size of the housing bust is defined as the percentage decline in house prices from the peak to the trough.

\textsuperscript{46}Note that transaction prices in the housing market are endogenous in our model. To make the model consistent with the data, we choose the decline in construction costs in the two locations such that the decline in house-sales prices in the model exactly matches the decline observed in the data.
and house price shocks backed out through the model.\footnote{Households’ expectations are derived from the stochastic process of labor productivity. In other words, households expect these shocks to recover according to the $AR(1)$ coefficient.} In our data, labor productivity declined by 1 percent in MSAs in location $A$ and by 5 in MSAs assigned to location $B$. In the second simulation, which we call the counterfactual simulation, we feed into the model the same realizations of labor productivity for locations $A$ and $B$. The parameters for housing construction costs do not change in this simulation, and, as a result, house prices decline by a much smaller amount.

\section*{11.1 Migration Rates}

We start reporting the decline in migration rates. It is important that the decline in migration is consistent with the decline in the data, because according to our hypothesis, the decline in migration is the driving force behind the increase in unemployment dispersion. The factual simulation shows that our model generates a sizable decline in both gross and net migration rates, consistent with the data. Note that the decline in migration rates is not targeted at any point of estimation. Table 16 summarizes the migration rates generated in the factual simulation. The model predicts a decline to 0.2 percent in net migration from a prerecession level of 0.8 percent. The empirical counterpart of this, obtained through IRS data, shows a decline from 0.8 percent to 0.3 percent. For gross flows, the model predicts a decline from 4.3 percent to 3.3 percent, compared to a decline in the gross migration rate from 4.3 percent to 3.8 percent.

To isolate the effect of the housing bust on migration, we use our model to see what would have happened to migration rates in the absence of the housing bust. The last column of Table 17 shows net migration rates predicted by the counterfactual experiment. Interest-
ingly, the model predicts a rise in net migration. Without the housing bust, responding to the asymmetric decline in labor productivity, more households would have migrated. As a result, the model generates an increase in net migration from 0.8 percent to 1.1 percent. However, in the factual simulation, the decline in house prices constrains the mobility of homeowners and results in a decline in net migration from 0.8 percent to 0.2 percent. The comparison of the two simulations indicates that the decline in migration caused by the housing bust is 0.8 percent, larger than the observed decline in the data. The decline in migration observed during the Great Recession is only 62.5 percent of the entire decline caused by the housing bust.

Figure 12 depicts the model’s prediction for the gross migration rate. The model generates a fall by around one percentage point from its prerecession level during the Great Recession (shown in the dashed-dotted line). The counterfactual simulation (shown in the solid line) indicates that, absent the housing bust, gross migration would have increased to 5.3 percent. Similar to the net migration rate, the model predicts a rise in the gross migration rate in the counterfactual analysis without the housing bust. We conclude that the observed decline in migration (both gross and net) in the data constitutes only half the decline caused by the housing bust.

To understand why geographical reallocation declines as a result of the house price decline, we now investigate the policy rules of homeowners for migration. Figure 13 shows the optimal policy rule for migration of a homeowner with 80 percent leverage that currently resides in location B. The x-axis is the productivity at location A, and the y-axis is the preference of the household for B, its current residence. The policy rule illustrates the trade-offs between the two factors governing the decision to migrate: preference shocks and
differences in local labor market conditions. Fixing the preference in the current location, a higher labor productivity in $A$ makes households in $B$ more likely to move out from their current residence. As the counterfactual simulation results indicate, in the absence of additional frictions coming from the housing market, the asymmetric decline in labor productivity during the Great Recession increases the benefit of migration, and thus workers in the relatively more distressed labor market move out.

Similarly, for a given level of labor productivity in $A$, only households below a cutoff preference enter the housing market to sell their houses. Those that successfully sell then move to location $A$. The top line shows the cutoff preference before the housing bust, while the bottom line shows the one after the housing bust. As the figure shows, the cutoff preference shifts down, suggesting that many households that would have moved decide to stay (thereby creating the region in the figure labeled “locked-in households”). The quantitative analysis suggests that the latter effect dominates the former and leads to a decline in geographical reallocation.

11.2 Geographical Dispersion of Unemployment Rates

This section studies the implications of the “house-lock” on local unemployment rates. The left panel of Figure 14 shows local unemployment rates in the simulation with house price declines and labor productivity shocks, and the right panel shows local unemployment rates in the counterfactual simulation (labor productivity shocks only). In both panels, we plot the deviation of unemployment from the level before the recession. The model predicts a rise in local unemployment by around 1.5 percentage points in $A$ and 4 percentage points in $B$. In the data, the rise is around 4.5 and 7 percentage points for locations $A$ and $B$, respectively.
respectively. The right panel in Figure 14 highlights the role of the housing bust in local unemployment. Without the housing bust, the model predicts a rise in local unemployment of 2 and 2.5 percentage points for locations A and B, respectively. Thus, the housing bust increases the unemployment rate further in B (large housing bust region) while decreasing it in A (small housing bust region).

As a consequence of the house-lock, many unemployed homeowners that would normally be looking for jobs in the other location now look for jobs in B. This causes local unemployment in B to rise more in response to a labor productivity decline. At the same time, it causes unemployment in A to rise less, since the households that would be unemployed and looking for jobs in A are now still in B. This mechanism results in an increase in the dispersion of unemployment across these two locations: A faces a lower decline in labor productivity, and the housing bust decreases the effect of the labor productivity shock on local unemployment, whereas B faces a higher decline in labor productivity, and the housing bust amplifies the effect on local unemployment.

Figure 15 plots the evolution of the difference of local unemployment rates between these two locations. The dashed line shows the data. In the solid line, we plot the difference in the simulation with both types of shocks, whereas in the dashed-dotted line we show the difference in the counterfactual simulation. We conclude that the housing bust substantially increases the model’s ability to capture the rise in the dispersion of unemployment rates across MSAs.
11.3 Aggregate Unemployment Rate

Our model allows us to study the effects of the housing bust on aggregate unemployment. Results in the previous sections suggest that the housing bust increases the fraction of unemployed workers that look for jobs in the low-productivity location. Therefore, one would expect the housing bust to further increase aggregate unemployment. Figure 16 shows the evolution of the aggregate unemployment rate for the two simulations. The asymmetric decline in labor productivity, accompanied by an asymmetric decline in house prices, results in an increase in unemployment of around 2.5 percentage points (shown in the solid line). The blue line reveals that the increase in the aggregate unemployment rate would have been around 2 percentage points had there been no housing bust. We conclude that the effect of the housing bust on aggregate unemployment rate is 0.5 percentage points. This may seem in contrast with the large effects on gross and net migration rates as well as on the dispersion of unemployment. This inconsistency can be easily reconciled by noting that the housing bust has opposite effects on the two locations. Location A is having a relatively lower unemployment rate compared to a recession without a housing bust because of the decline of the inflow of unemployed households from location B. Location B, however, has a higher unemployment than in a counterfactual recession because of the locked-in unemployed homeowners. Thus, it is not clear ex ante in which direction the aggregate unemployment rate would respond. Our quantitative exercise suggests that despite large effects on migration and local unemployment rates, this mechanism can explain a small fraction of aggregate unemployment.
11.4 Homeowners and Renters during the Great Recession

The mechanism evaluated in this paper operates through lower migration and higher unemployment rates for homeowners caused by an unexpected decline in house prices. One might wonder if the experience of renters during the Great Recession was drastically different than that of homeowners. Using data from the Survey of Income and Program Participants, Aaronson and Davis (2011) show that while the migration rate of homeowners declined during the recession, the migration rate of renters declined by a similar magnitude. Valletta (2012), using data from the Current Population Survey, documents that during the Great Recession unemployment duration of renters and homeowners increased by similar magnitudes. These studies conclude that the effect of the housing bust on migration and unemployment has been economically insignificant. Our model, however, predicts a small rise in renter migration rate and a rise in renter unemployment duration that is smaller than the rise in homeowner unemployment duration.

An important identifying assumption common to all of these studies is that renters’ migration behavior is not affected by the decline in house prices. This is an assumption that we question in a related paper: Karahan and Rhee (2014) show that there can be substantial spillover effects, i.e., a decline in the migration rate of one group of workers (the treatment group, say, homeowners) may induce a decline in the migration rate of other groups (the control group, say, renters), due to general equilibrium effects in the labor market. More strikingly, the decline in the migration rate of the control group may be larger than that of the treatment group. This result puts the identification strategy in the aforementioned studies in question. Therefore, we do not view these studies as contradicting the main
mechanism pursued in this paper.

12 Conclusions

We have developed a computationally tractable equilibrium model of multiple locations with local housing and labor markets and used it to study the effects of the housing bust on local and aggregate labor markets during the Great Recession. Our analysis suggests that the housing bust is responsible for the decline of migration and the increase in the dispersion of unemployment across regions. A reduction in house prices reduces the home equity for households and causes the down payment constraint to bind for more households. It is because households prefer owning over renting that the decline in house prices distorts their migration decisions. Consequently, unemployment in the low-productivity region responds strongly to the decline in productivity, whereas the rise in the relatively better location is lower, due to a reduction in the inflow of unemployed workers. The opposite effects drive up the dispersion in unemployment but result in a smaller rise in aggregate unemployment. Despite a large decline in geographical reallocation and the resulting rise in unemployment dispersion, we found that the housing bust accounts for 0.5 percentage points of the rise in aggregate unemployment.

The model presented in this paper provides a quantitative framework for future research on housing and labor markets. Housing markets may affect various aspects of local labor markets, including local wages, local unemployment rates, inflow and outflow of workers, and the time it takes for the region to recover from adverse shocks. Our model has the essential ingredients to evaluate how policies that affect homeownership and housing debt
influence local and aggregate labor market outcomes.

Several European countries are characterized by large and persistent unemployment differences across regions. They also typically have more rigid housing markets. Is there a link between the housing and rental market structure and unemployment dispersion? The model developed in this paper can be modified to study the implications of these differences for the labor markets in those countries. We defer this work to ongoing and future research.

13 Tables

<table>
<thead>
<tr>
<th>Table 10</th>
<th>Labor Productivity Process</th>
</tr>
</thead>
<tbody>
<tr>
<td>Parameter</td>
<td>$\rho$</td>
</tr>
<tr>
<td>Value</td>
<td>0.98</td>
</tr>
</tbody>
</table>

Note: Results of the estimation of an AR(1) process on the log of local labor productivity (output per worker).
### Table 11
Model Parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Precalibrated</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\alpha$</td>
<td>10%</td>
<td>down payment requirement</td>
</tr>
<tr>
<td>$r$</td>
<td>0.25%</td>
<td>monthly interest rate</td>
</tr>
<tr>
<td>$b$</td>
<td>0.4</td>
<td>unemployment benefits</td>
</tr>
<tr>
<td>$\zeta_0$</td>
<td>0</td>
<td>consumption flow from renting</td>
</tr>
<tr>
<td>$\delta$</td>
<td>3.4%</td>
<td>job destruction probability</td>
</tr>
<tr>
<td>Within-the-model</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\zeta_1$</td>
<td>0.20</td>
<td>consumption flow from owning</td>
</tr>
<tr>
<td>$\beta$</td>
<td>0.984</td>
<td>discount rate</td>
</tr>
<tr>
<td>$\lambda$</td>
<td>0.51</td>
<td>home production</td>
</tr>
<tr>
<td>$k$</td>
<td>0.75</td>
<td>vacancy posting cost for firms</td>
</tr>
<tr>
<td>$\gamma_l$</td>
<td>1.80</td>
<td>labor market elasticity</td>
</tr>
<tr>
<td>$\kappa$</td>
<td>0.12</td>
<td>vacancy posting cost for REMs</td>
</tr>
<tr>
<td>$\gamma_b, \gamma_s$</td>
<td>0.80</td>
<td>housing market matching functions</td>
</tr>
<tr>
<td>$\rho_\psi$</td>
<td>0.991</td>
<td>persistence of the preference shock</td>
</tr>
<tr>
<td>$\sigma_\psi$</td>
<td>0.002</td>
<td>standard deviation of preference shocks</td>
</tr>
<tr>
<td>$\mu$</td>
<td>48</td>
<td>housing construction cost</td>
</tr>
<tr>
<td>$\gamma$</td>
<td>0.05</td>
<td>depreciation rate of rental houses</td>
</tr>
</tbody>
</table>

Note: Table 11 reports the calibrated parameter values of the model. The upper panel reports parameters calibrated a priori. The lower panel reports the parameters calibrated within the model.
**Table 12**  
**Matching the Calibration Targets**

<table>
<thead>
<tr>
<th>Moment</th>
<th>Data</th>
<th>Model</th>
</tr>
</thead>
<tbody>
<tr>
<td>Homeownership rate</td>
<td>69%</td>
<td>69%</td>
</tr>
<tr>
<td>Average time to sell (in months)</td>
<td>3.5</td>
<td>3.5</td>
</tr>
<tr>
<td>Genesove and Mayer (1997)</td>
<td>15%</td>
<td>15%</td>
</tr>
<tr>
<td>Job finding probability</td>
<td>0.45</td>
<td>0.44</td>
</tr>
<tr>
<td>Elasticity of job finding probability</td>
<td>0.95</td>
<td>0.94</td>
</tr>
<tr>
<td>Volatility of $p(\theta)/z$</td>
<td>5.5</td>
<td>5.5</td>
</tr>
<tr>
<td>Median leverage</td>
<td>67%</td>
<td>67%</td>
</tr>
<tr>
<td>House price/monthly wage</td>
<td>48</td>
<td>48</td>
</tr>
<tr>
<td>Gross mobility</td>
<td>4.3%</td>
<td>4.3%</td>
</tr>
<tr>
<td>Net mobility</td>
<td>0.8%</td>
<td>0.8%</td>
</tr>
</tbody>
</table>

Note: Table 12 reports calibration targets and their values from the model. See the discussion in the text for detailed information on the targets.

**Table 13**  
**Volatility of Gross and Net Flows**

<table>
<thead>
<tr>
<th>Standard Deviation</th>
<th>Model</th>
<th>Data</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gross migration</td>
<td>0.35</td>
<td>0.22</td>
</tr>
<tr>
<td>Net migration</td>
<td>0.20</td>
<td>0.12</td>
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</table>

**Table 14**  
**Local Productivity and Population Flows**

<table>
<thead>
<tr>
<th>$outflow_{i,t}$</th>
<th>Model</th>
<th>Data</th>
</tr>
</thead>
<tbody>
<tr>
<td>Relative productivity</td>
<td>−0.011</td>
<td>−0.0047</td>
</tr>
<tr>
<td>$\log(z_t) - \log(z_{i,t})$</td>
<td>(0.0019)</td>
<td></td>
</tr>
</tbody>
</table>
Table 15
Cyclicality of Gross Flows

<table>
<thead>
<tr>
<th>log grossflow_t</th>
<th>Model</th>
<th>Data</th>
</tr>
</thead>
<tbody>
<tr>
<td>Log unemployment</td>
<td>−0.009</td>
<td>−0.011</td>
</tr>
<tr>
<td>Log(u_t)</td>
<td>(0.004)</td>
<td></td>
</tr>
</tbody>
</table>

Table 16
Migration: Data vs. Model

<table>
<thead>
<tr>
<th></th>
<th>Data</th>
<th>Model</th>
</tr>
</thead>
<tbody>
<tr>
<td>Year</td>
<td>Gross migration (%)</td>
<td>Net migration (%)</td>
</tr>
<tr>
<td>2006–2007</td>
<td>4.3</td>
<td>0.8</td>
</tr>
<tr>
<td>2007–2008</td>
<td>4.1</td>
<td>0.5</td>
</tr>
<tr>
<td>2008–2009</td>
<td>3.8</td>
<td>0.3</td>
</tr>
</tbody>
</table>

Note: Table 16 compares the gross and net migration rates in the data and the model.
Table 17
Net Migration: Data vs. Model

<table>
<thead>
<tr>
<th>Year</th>
<th>Data (%)</th>
<th>Model (%)</th>
<th>Counterfactual (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2006–2007</td>
<td>0.8</td>
<td>0.8</td>
<td>0.8</td>
</tr>
<tr>
<td>2007–2008</td>
<td>0.5</td>
<td>0.3</td>
<td>1.6</td>
</tr>
<tr>
<td>2008–2009</td>
<td>0.3</td>
<td>0.2</td>
<td>1.1</td>
</tr>
</tbody>
</table>

Note: Table 17 compares the net migration rates in the data and the model. The last column shows the net migration rate predicted by the model in the absence of a housing bust.
Figure 12
GROSS MIGRATION AND THE HOUSING BUST

Note: Figure shows the gross migration rate predicted by the model. The blue line shows the decline in migration as a result of the housing bust and decline in labor productivity. The green line shows the counterfactual migration rate that would have obtained absent the housing bust. The model predicts a rise in migration. The difference between the two lines is the true effect of the housing bust on migration.
Figure 13

Cutoff Rule for Migration

Note: Figure shows the migration decision of a household with 80% leverage living in location B. X-axis is the labor productivity in location A, and the y-axis is the preference of the household for the current residence, location B. The migration decision is characterized by a cutoff rule that is increasing in the productivity of the other location. The cutoff shifts down when house prices in MSA B fall. The shaded area designates the set of households that do not move due to the housing bust. We label them as locked-in households.
Figure 14

Local Unemployment and the Housing Bust

Note: Figure shows the unemployment rate for location A and location B. We plot the deviation from the unemployment rate before the recession. The left panel shows the simulation with a house price shock as well as a labor productivity shock. The right panel plots the case where the model is hit by a labor productivity shock only.
Note: Figure compares the prediction of the model for the difference in unemployment rates between location A and location B with the data. The solid line shows the difference that arises as a result of labor productivity and house price shock. The dashed-dotted line shows the effect of the decline in labor productivity without a housing bust. The dashed line is data.
Figure 16

AGGREGATE UNEMPLOYMENT AND THE HOUSING BUST

Note: In the solid line, we show the rise in aggregate unemployment as a response to house price and labor productivity shocks. The dashed line shows the rise with a labor productivity shock but without a housing bust. Finally, the dashed-dotted line shows the data.
Chapter III

Appendix to Chapter 1

A Additional Figures and Tables

<table>
<thead>
<tr>
<th>VARIABLES</th>
<th>(1)</th>
<th>(2)</th>
<th>(3)</th>
</tr>
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<tbody>
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<td></td>
<td>All Population</td>
<td>Older than 40</td>
<td>Younger than 40</td>
</tr>
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<td>Log Income</td>
<td>-0.0003***</td>
<td>-0.0002*</td>
<td>-0.0005***</td>
</tr>
<tr>
<td></td>
<td>(0.0000)</td>
<td>(0.0000)</td>
<td>(0.0001)</td>
</tr>
<tr>
<td>Age</td>
<td>-0.0009***</td>
<td>0.0000</td>
<td>-0.0021***</td>
</tr>
<tr>
<td></td>
<td>(0.0000)</td>
<td>(0.0000)</td>
<td>(0.0006)</td>
</tr>
<tr>
<td>Age Squared</td>
<td>8.37e-06***</td>
<td>2.49e-07</td>
<td>2.37e-05***</td>
</tr>
<tr>
<td></td>
<td>(0.0000)</td>
<td>(2.76e-06)</td>
<td>(0.0000)</td>
</tr>
<tr>
<td>College Binary</td>
<td>0.0036***</td>
<td>0.0014***</td>
<td>0.0069***</td>
</tr>
<tr>
<td></td>
<td>(0.0003)</td>
<td>(0.0003)</td>
<td>(0.0004)</td>
</tr>
<tr>
<td>Employment Indicator</td>
<td>-0.0082***</td>
<td>-0.0069***</td>
<td>-0.0111***</td>
</tr>
<tr>
<td></td>
<td>(0.0006)</td>
<td>(0.0006)</td>
<td>(0.0010)</td>
</tr>
<tr>
<td>Labor Force Indicator</td>
<td>0.0028***</td>
<td>0.0024***</td>
<td>0.0036***</td>
</tr>
<tr>
<td></td>
<td>(0.0002)</td>
<td>(0.0002)</td>
<td>(0.0003)</td>
</tr>
<tr>
<td>Married Indicator</td>
<td>0.0002</td>
<td>0.0005***</td>
<td>0.0000</td>
</tr>
<tr>
<td></td>
<td>(0.0002)</td>
<td>(0.0002)</td>
<td>(0.0003)</td>
</tr>
<tr>
<td>Share Above 40</td>
<td>-0.0101***</td>
<td>-0.0064**</td>
<td>-0.0159***</td>
</tr>
<tr>
<td></td>
<td>(0.0028)</td>
<td>(0.0026)</td>
<td>(0.0052)</td>
</tr>
<tr>
<td>State Population</td>
<td>-0.0014***</td>
<td>-0.0008***</td>
<td>-0.0023***</td>
</tr>
<tr>
<td></td>
<td>(0.0001)</td>
<td>(0.0001)</td>
<td>(0.0002)</td>
</tr>
<tr>
<td>State Unemployment</td>
<td>0.0000</td>
<td>0.0002</td>
<td>0.0000</td>
</tr>
<tr>
<td></td>
<td>(0.0006)</td>
<td>(0.0004)</td>
<td>(0.0009)</td>
</tr>
<tr>
<td>State Income</td>
<td>0.0024***</td>
<td>0.0019***</td>
<td>0.0031***</td>
</tr>
<tr>
<td></td>
<td>(0.0005)</td>
<td>(0.0005)</td>
<td>(0.0008)</td>
</tr>
</tbody>
</table>

Note: Table 18 shows the marginal effects from probit regressions using the SIPP data. The dependent variable is an outflow dummy that takes a value of 1 if the individual is living in a different location 3 months after the survey. Column (1) reports the results on the entire working age population. Column (2) and (3) report the results on a sample of workers older and younger than 40, respectively. The results show that an increase in the share of older population in a state is associated with a substantial decline in the outflow rate to that state. This effect is particularly strong for young individuals.

Standard errors in parentheses, clustered by state. *** p<0.01, ** p<0.05, * p<0.1.
Table 19
State demographics and outflows (with year fixed effects)

<table>
<thead>
<tr>
<th>VARIABLES</th>
<th>(1)</th>
<th>(2)</th>
<th>(3)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Log Income</td>
<td>-0.0003***</td>
<td>-0.0002**</td>
<td>-0.0005***</td>
</tr>
<tr>
<td></td>
<td>(0.0000)</td>
<td>(0.0000)</td>
<td>(0.0001)</td>
</tr>
<tr>
<td>Age</td>
<td>-0.0009***</td>
<td>0.0000</td>
<td>-0.0020***</td>
</tr>
<tr>
<td></td>
<td>(0.0000)</td>
<td>(0.000275)</td>
<td>(0.0006)</td>
</tr>
<tr>
<td>Age Squared</td>
<td>8.32e-06***</td>
<td>0.0000</td>
<td>2.36e-05***</td>
</tr>
<tr>
<td></td>
<td>(0.0000)</td>
<td>(0.0000)</td>
<td>(0.0000)</td>
</tr>
<tr>
<td>College Binary</td>
<td>0.0036***</td>
<td>0.0014***</td>
<td>0.0069***</td>
</tr>
<tr>
<td></td>
<td>(0.0003)</td>
<td>(0.0002)</td>
<td>(0.0004)</td>
</tr>
<tr>
<td>Employment Indicator</td>
<td>-0.0082***</td>
<td>-0.0068***</td>
<td>-0.0111***</td>
</tr>
<tr>
<td></td>
<td>(0.0006)</td>
<td>(0.0006)</td>
<td>(0.0010)</td>
</tr>
<tr>
<td>Labor Force Indicator</td>
<td>0.0028***</td>
<td>0.0024***</td>
<td>0.0036***</td>
</tr>
<tr>
<td></td>
<td>(0.0002)</td>
<td>(0.0002)</td>
<td>(0.0003)</td>
</tr>
<tr>
<td>Married Indicator</td>
<td>0.0002</td>
<td>0.0005***</td>
<td>0.0000</td>
</tr>
<tr>
<td></td>
<td>(0.0002)</td>
<td>(0.0002)</td>
<td>(0.0003)</td>
</tr>
<tr>
<td>Share Above 40</td>
<td>-0.0149**</td>
<td>-0.0069</td>
<td>-0.0274***</td>
</tr>
<tr>
<td></td>
<td>(0.0063)</td>
<td>(0.0070)</td>
<td>(0.0092)</td>
</tr>
<tr>
<td>State Population</td>
<td>-0.0014***</td>
<td>-0.0008***</td>
<td>-0.0023***</td>
</tr>
<tr>
<td></td>
<td>(0.0001)</td>
<td>(0.0001)</td>
<td>(0.0002)</td>
</tr>
<tr>
<td>State Unemployment</td>
<td>0.0000</td>
<td>0.0002</td>
<td>0.0000</td>
</tr>
<tr>
<td></td>
<td>(0.0008)</td>
<td>(0.0006)</td>
<td>(0.0013)</td>
</tr>
<tr>
<td>State Income</td>
<td>0.0021***</td>
<td>0.0019***</td>
<td>0.0023**</td>
</tr>
<tr>
<td></td>
<td>(0.0007)</td>
<td>(0.0006)</td>
<td>(0.0009)</td>
</tr>
</tbody>
</table>

Note: Table 18 shows the marginal effects from probit regressions using the SIPP data, controlling for time effects. The dependent variable is an outflow dummy that takes a value of 1 if the individual is living in a different location 3 months after the survey. Column (1) reports the results on the entire working age population. Column (2) and (3) report the results on a sample of workers older and younger than 40, respectively. The results show that an increase in the share of older population in a state is associated with a substantial decline in the outflow rate to that state. This effect is particularly strong for young individuals. Standard errors in parentheses, clustered by state. *** p<0.01, ** p<0.05, * p<0.1.
Table 20  
CROSS-SECTIONAL REGRESSIONS: STATE DEMOGRAPHICS AND INFLOW RATES

<table>
<thead>
<tr>
<th>VARIABLES</th>
<th>(1)</th>
<th>(2)</th>
<th>(3)</th>
<th>(4)</th>
<th>(5)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Log(inflow rate)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Share of pop. &gt;40</td>
<td>-3.3880*** (0.989)</td>
<td>-4.3382*** (0.611)</td>
<td>-4.4225*** (0.572)</td>
<td>-3.4794*** (0.826)</td>
<td>-4.0856*** (0.736)</td>
</tr>
<tr>
<td>Income per capita</td>
<td>1.0222*** (0.117)</td>
<td>1.0238*** (0.116)</td>
<td>0.8430*** (0.185)</td>
<td>0.8844*** (0.169)</td>
<td></td>
</tr>
<tr>
<td>Unemployment</td>
<td>-0.0782 (0.128)</td>
<td>-0.1225 (0.134)</td>
<td>-0.0220 (0.124)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Homeownership</td>
<td>-0.9316 (0.708)</td>
<td>-0.5417 (0.610)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Population</td>
<td></td>
<td></td>
<td></td>
<td>-0.1246** (0.056)</td>
<td></td>
</tr>
</tbody>
</table>

Observations: 918 918 918 918 918  
R-squared: 0.078 0.305 0.307 0.325 0.374

Note: Table 20 shows the cross-sectional relationship across states between the share of individuals older than 40 and the inflow rate. The regressors are all in logs except for the share of working population older than 40. The results show that an increase in the share of older population in a state is associated with a substantial decline in the inflow rate to that state. This effect prevails even after controlling for other observable differences across states. Standard errors in parentheses, clustered by state. *** p<0.01, ** p<0.05, * p<0.1.
<table>
<thead>
<tr>
<th>VARIABLES</th>
<th>(1)</th>
<th>(2)</th>
<th>(3)</th>
<th>(4)</th>
<th>(5)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Share of pop. &gt;40</td>
<td>-1.0414***</td>
<td>-1.6721***</td>
<td>-1.4044***</td>
<td>-1.2731***</td>
<td>-1.1040***</td>
</tr>
<tr>
<td></td>
<td>(0.214)</td>
<td>(0.416)</td>
<td>(0.434)</td>
<td>(0.442)</td>
<td>(0.377)</td>
</tr>
<tr>
<td>Income per capita</td>
<td>0.2337</td>
<td>0.0832</td>
<td>0.0882</td>
<td>0.3796***</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.155)</td>
<td>(0.158)</td>
<td>(0.155)</td>
<td>(0.121)</td>
<td></td>
</tr>
<tr>
<td>Unemployment</td>
<td>-0.1743***</td>
<td>-0.1792***</td>
<td>-0.1434***</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.026)</td>
<td>(0.027)</td>
<td>(0.023)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Homeownership</td>
<td>-0.2363</td>
<td>-0.0537</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.292)</td>
<td>(0.224)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Population</td>
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<td></td>
<td></td>
<td></td>
<td>-0.9444***</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>(0.141)</td>
</tr>
<tr>
<td>Observations</td>
<td>918</td>
<td>918</td>
<td>918</td>
<td>918</td>
<td>918</td>
</tr>
<tr>
<td>R-squared</td>
<td>0.111</td>
<td>0.124</td>
<td>0.220</td>
<td>0.223</td>
<td>0.341</td>
</tr>
</tbody>
</table>

Note: Table 21 shows the results of fixed effect regressions, where the dependent variable is the log of inflow rate to a state and the main regressor is the share of individuals older than 40. The regressors are all in logs except for the share of working population older than 40. The results show that an increase in the share of older population in a state is associated with a substantial decline in the inflow rate to that state. This effect prevails even after controlling for other observable differences across states. Standard errors in parentheses, clustered by state. *** p<0.01, ** p<0.05, * p<0.1.
Note: Figure 17 shows the cross-sectional relationship between the fraction of older population and the inflow rate across states. We first group the states in 10 percentiles according to the fraction of individuals older than 40. The x-axis is the mean of this fraction over all states in a percentile, whereas the y-axis is the average inflow rate of states in a percentile. The figure shows that states with a higher fraction of older population receive less inflows. Source: IRS population flows, March CPS, and authors’ calculations.

B Proofs of Propositions in Section 3

B.1 Proof of Remark 1

From the value of a firm with an employee,

\[ J(w) = y - w + \beta (1 - \delta) J(w) \]

\[ J(w) = \frac{y - w}{1 - \beta (1 - \delta)}. \]

Under the Nash bargaining, the equilibrium wage satisfies

\[ J(w^*) = (1 - \eta) S^j, \]
where $j$ indicates the type of worker. Combining the above two equations,

$$w^s = y - \{1 - \beta (1 - \delta)\} (1 - \eta) S^s$$

$$w^n_l = y - \{1 - \beta (1 - \delta)\} (1 - \eta) S^n_l$$

$$w^n_d = y - \{1 - \beta (1 - \delta)\} (1 - \eta) S^n_d,$$

or

$$w^s = \eta y \left[ \frac{1 - \beta \{(1 - \delta) - p(\theta_1)\}}{1 - \beta \{(1 - \delta) - \eta p(\theta_1)\}} \right] + (1 - \eta) b \left[ \frac{1 - \beta (1 - \delta)}{1 - \beta \{(1 - \delta) - \eta p(\theta_1)\}} \right]$$

$$w^n_l = \eta y \left[ \frac{1 - \beta \{(1 - \delta) - p(\theta_1) - (1 - \eta p(\theta_1)) p(\theta_d)\}}{1 - \beta \{1 - \eta p(\theta_1) - (1 - \eta p(\theta_1)) \eta p(\theta_d)\}} \right]$$

$$+ \eta y \left[ \frac{1 - \beta \{(1 - \delta) - \eta p(\theta_1) - (1 - \eta p(\theta_1)) \eta p(\theta_d)\}}{1 - \beta \{1 - \eta p(\theta_1) - (1 - \eta p(\theta_1)) \eta p(\theta_d)\}} \right]$$

$$w^n_d = \eta y \left[ \frac{1 - \beta \{(1 - \delta) - p(\theta_1) - (1 - \eta p(\theta_1)) p(\theta_d)\}}{1 - \beta \{1 - \eta p(\theta_1) - (1 - \eta p(\theta_1)) \eta p(\theta_d)\}} \right]$$

$$+ (1 - \eta) b \left[ \frac{1 - \beta (1 - \delta)}{1 - \beta \{(1 - \delta) - \eta p(\theta_1) - (1 - \eta p(\theta_1)) \eta p(\theta_d)\}} \right].$$

### B.2 Proof of Proposition 1

Using the Nash bargaining solution, we can rewrite the free-entry conditions as follows:

$$\kappa = q(\theta_d) (1 - \eta) S^*_d(\theta_l, \theta_d)$$

$$\kappa = q(\theta_l) (1 - \eta) \left\{ \frac{u^s}{u^n + u^s} S^s(\theta_l, \theta_d) + \frac{u^n}{u^n + u^s} S^n_l(\theta_l, \theta_d) \right\}. \quad (37)$$
The steady state measure of type $j$ unemployed workers in location $i$, $u^j_i$, is determined by imposing the steady state condition on the following law of motions:

$$
u^s_{i,t+1} = (1 - p(\theta^j_i)) \nu^s_{i,t} + \delta (\phi - u^s_{i,t})$$

$$
u^n_{i,t+1} = \left\{1 - p(\theta^i_i) - (1 - p(\theta^j_i)) p(\theta^j_d) \right\} \nu^n_{i,t} + \delta e^n_{i,t}$$

$$e^n_{i,t+1} = (1 - \delta) e^n_{i,t} + p(\theta^i_i) \nu^n_i + \left(1 - p(\theta^j_i) \right) p(\theta^j_d) u^j_i.$$ 

From the symmetric equilibrium condition,

$$u^s = \frac{\delta \phi}{\delta + p(\theta^i_i)}$$

$$e^n = \frac{\left\{p(\theta^j_i) + (1 - p(\theta^j_i)) p(\theta_d) \right\} \left(0.5 - \phi \right)}{\delta + p(\theta^i_i) + (1 - p(\theta^j_i)) p(\theta_d)}$$

and the ratio of unemployed workers between two types at the steady state is

$$\frac{u^s}{u^s + u^n} = \frac{\phi \left\{\delta + p(\theta^i_i) + (1 - p(\theta^j_i)) p(\theta_d) \right\}}{(0.5 - \phi) (p(\theta^i_i) + \delta) + \phi \left\{\delta + p(\theta^i_i) + (1 - p(\theta^j_i)) p(\theta_d) \right\}}.$$ 

This expression completes the two free-entry conditions as a set of two equations with two unknowns, $(\theta^i_i, \theta^j_d)$. We can rewrite the free-entry condition for the distant labor market such that

$$F(\theta^i_i, \theta^j_d) = \kappa [1 - \beta \{(1 - \delta) - \eta p(\theta^i_i) - (1 - \eta p(\theta^j_i) \eta p(\theta^j_d)) \}]$$

$$-q(\theta^j_d) (1 - \eta) (y - b) = 0.$$ 

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By applying the implicit function theorem on the equation (38),

\[ \frac{d\theta_d}{d\theta} = - \frac{dF}{d\theta} = \frac{\kappa \eta p' (\theta) (1 - p(\theta_d))}{q'(\theta_d) (1 - \eta) (y - b) - \kappa \eta (1 - p(\theta)) p' (\theta_d)} < 0. \quad (39) \]

Now we know \( \theta_d (\theta_l) \) and \( \theta_d' (\theta_l) < 0 \). For the local labor market,

\[ G(\phi, \theta_l) = \kappa - q(\theta_l) (1 - \eta) \left\{ \frac{u^s}{u^n + u^s} S^s + \frac{u^n}{u^n + u^s} S^n \right\} \]

\[ = \kappa - q(\theta_l) (1 - \eta) \left\{ \frac{u^s}{u^n + u^s} (S^s - S^n) + S^n \right\} = 0. \quad (40) \]

In the same way, we apply the implicit function theorem on the equation (40). First,

\[ \frac{\partial G}{\partial \phi} = - \frac{0.5 (p(\theta_l) + \delta) \{ \delta + p(\theta_l) + (1 - p(\theta)) p(\theta_d) \}}{\{0.5 (p(\theta_l) + \delta) + \phi (1 - p(\theta_l)) p(\theta_d)\}^2} < 0 \quad (41) \]

because

\[ \frac{\partial}{\partial \phi} \left( \frac{u^s}{u^n + u^s} \right) = \frac{0.5 \{ \delta + p(\theta_l) + (1 - p(\theta)) p(\theta_d) \} (p(\theta_l) + \delta)}{\{0.5 (p(\theta_l) + \delta) + \phi (1 - p(\theta_l)) p(\theta_d)\}^2} > 0 \]

and \( S^s - S^n_l > 0 \). From the definition of match surplus,

\[ S^n_l = \frac{(y - b) (1 - \eta p(\theta_d))}{1 - \beta \{ (1 - \delta) - \eta p(\theta_l) - (1 - \eta p(\theta)) \eta p(\theta_d) \}} \]

\[ = (1 - \eta p(\theta)) S^n_d. \]
Note that

\[
\frac{\partial S^n_d}{\partial \theta_l} = \frac{\beta (y - b) \eta p' (\theta_l) (1 - \eta p (\theta_d))}{\left[ 1 - \beta \{ 1 - \delta - \eta p (\theta_l) - (1 - \eta p (\theta_l)) \eta p (\theta_d) \} \right]^2} \times \frac{q' (\theta_d) (1 - \eta) (y - b)}{\kappa \beta (1 - \eta p (\theta_l)) \eta p' (\theta_d) - q' (\theta_d) (1 - \eta) (y - b)} < 0.
\]

Therefore,

\[
\frac{\partial S^n_d}{\partial \theta_l} = \frac{\partial}{\partial \theta_l} ((1 - \eta p (\theta_d)) S^n_d) = -\eta p' (\theta_d) \frac{\partial S^n_d}{\partial \theta_l} + (1 - \eta p (\theta_d)) \frac{\partial S^n_d}{\partial \theta_l}
\]

\[
= \frac{\beta \eta p' (\theta_l) (1 - \eta p (\theta_d)) (y - b)}{\Gamma (\theta_l, \theta_d)} \times \left[ \eta p' (\theta_d) + q' (\theta_d) (1 - \eta) \frac{1 - \beta \{ 1 - \delta - \eta p (\theta_l) - (1 - \eta p (\theta_l)) \eta p (\theta_d) \}}{1 - \beta \{ 1 - \delta - \eta p (\theta_l) - (1 - \eta p (\theta_l)) \eta p (\theta_d) \}} \right]
\]

\[
= \frac{\beta \eta p' (\theta_l) (1 - \eta p (\theta_d)) (y - b)}{\Gamma (\theta_l, \theta_d)} \times \left[ \eta p' (\theta_d) q (\theta_d) + q' (\theta_d) (1 - \eta p (\theta_d)) \right] (1 - \eta) S^n_d
\]

where

\[
\Gamma (\theta_l, \theta_d) = [1 - \beta \{ 1 - \delta - \eta p (\theta_l) - (1 - \eta p (\theta_l)) \eta p (\theta_d) \}]
\]

\[
\times [\kappa \beta (1 - \eta p (\theta_l)) \eta p' (\theta_d) - q' (\theta_d) (1 - \eta) (y - b)].
\]

Thus,

\[
\frac{\partial S^n_d}{\partial \theta_l} < 0
\]
if $\eta p'(\theta_d) q(\theta_d) + q'(\theta_d) (1 - \eta p(\theta_d)) > 0$, or

$$\eta < -\frac{q'(\theta_d)}{q(\theta_d)^2} = \frac{1 - \theta dp'}{p(\theta_d)}.$$  

For Cobb-Douglas matching function, the above condition can be written as follows:

$$p(\theta) < \frac{1 - \alpha}{\eta}.$$  

This conditions always holds if $1 - \alpha > \eta$ because $p(\theta) \in [0, 1]$. In this case,

$$\frac{\partial G}{\partial \theta_l} = -q'(\theta_l) (1 - \eta) \left\{ \frac{u^s}{u^n + u^s} S^s + \frac{u^n}{u^n + u^s} S^n \right\}$$

$$-q(\theta_l) (1 - \eta) \left\{ \frac{\partial}{\partial \theta_l} \left( \frac{u^s}{u^n + u^s} \right) (S^s - S^n) + \frac{u^s}{u^n + u^s} \frac{\partial S^s}{\partial \theta_l} + \frac{u^n}{u^n + u^s} \frac{\partial S^n}{\partial \theta_l} \right\}$$

$$> 0,$$

because

$$\frac{\partial}{\partial \theta_l} \left( \frac{u^s}{u^n + u^s} \right)$$

$$= \phi (0.5 - \phi)$$

$$\times \left\{ \frac{(p(\theta_l) + \delta) (1 - p(\theta_l)) p'(\theta_d) \frac{\partial \theta_d}{\partial \theta_l}}{0.5 (p(\theta_l) + \delta) + \phi (1 - p(\theta_l)) p(\theta_d)^2} \right\}$$

$$\times \left\{ \frac{-p'(\theta_l) \{(p(\theta_l) + \delta) p(\theta_d) + (1 - p(\theta_l)) p(\theta_d)\}}{0.5 (p(\theta_l) + \delta) + \phi (1 - p(\theta_l)) p(\theta_d)^2} \right\}$$

$$< 0$$

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and

\[
\frac{\partial S^s}{\partial \theta_l} = - \frac{(y - b) \beta \eta p' (\theta_l)}{\{1 - \beta (1 - \delta) + \beta \eta p (\theta_l)\}^2} < 0.
\]

Thus

\[
\frac{d\theta_l}{d\phi} = - \frac{\partial G}{\partial \phi} \frac{\partial G}{\partial \theta_l} > 0.
\]

Combining the above result with (39),

\[
\frac{d\theta_d}{d\phi} < 0.
\]

### B.3 Proof of Corollary 2

The migration rate of mobile workers is defined as the share of workers moved out of total number of mobile households. At the steady state, the population flow between the two places is equal to \(2 (1 - p (\theta_l)) p (\theta_d) u^1\). Therefore,

\[
mr (\theta_l, \theta_d) = \frac{2 (1 - p (\theta_l)) p (\theta_d) u^1}{2 (e^1 + u^1)}
\]

\[
= \frac{(1 - p (\theta_l)) p (\theta_d)}{0.5 - \phi} \times \frac{\delta (0.5 - \phi)}{\delta + p (\theta_l) + (1 - p (\theta_l)) p (\theta_d)}
\]

\[
= \frac{\delta (1 - p (\theta_l)) p (\theta_d)}{\delta + p (\theta_l) + (1 - p (\theta_l)) p (\theta_d)} + \frac{1}{(1 - p (\theta_l)) p (\theta_d) + 1}
\]

In proposition (1), we prove that \(\frac{d\theta_d}{d\phi} < 0\) and \(\frac{d\theta_l}{d\phi} > 0\) and the job finding rate is positively correlated with the market tightness \(\theta\): \(p' (\theta) > 0\). Thus the increase in immobile households increases the denominator of the steady state migration rate of mobile households (43),
resulting lower migration rate.

\[
\frac{dmr}{d\phi} < 0
\]

**B.4 Proof of Corollary 3**

The unemployment rate of settlers is

\[
ur^s(\theta_l) = \frac{2u^s}{2\phi} = \frac{\delta \phi}{\delta + p(\theta_l)} = \frac{\delta}{\delta + p(\theta_l)}.
\]

It is straightforward to show that the unemployment rate of immobile households decreases as the local job finding rate \( p(\theta_l) \) is increasing function of \( \phi \). For nomads, the conditional unemployment rate is

\[
ur^n(\theta_l, \theta_d) = \frac{2u^n}{2(0.5 - \phi)} = \frac{\delta (0.5 - \phi)}{\delta + p(\theta_l) + (1 - p(\theta_l)) p(\theta_d)} = \frac{\delta}{\delta + p(\theta_l) + (1 - p(\theta_l)) p(\theta_d)}.
\]
Using the equation (39) and \( \Phi (\theta_d, \theta_l) \equiv q' (\theta_d) (1 - \eta) (y - b) - \kappa \beta \eta (1 - p (\theta_l)) p' (\theta_d) \),

\[
\frac{d\text{ur}^n}{d\phi} = - p' (\theta_l) \frac{dn}{d\phi} (1 - p (\theta_d)) + (1 - p (\theta_l)) p' (\theta_d) \frac{dn}{d\phi} \frac{dn}{d\phi}
\]

\[
= - \left( \frac{d\theta_l}{d\phi} \right) \times \frac{p' (\theta_l) (1 - p (\theta_d)) + (1 - p (\theta_l)) p' (\theta_d) \frac{dp}{d\phi}}{\{\delta + p (\theta_l) + (1 - p (\theta_l)) p (\theta_d)\}^2}
\]

\[
= - \left( \frac{d\theta_l}{d\phi} \right) \times \frac{1}{\{\delta + p (\theta_l) + (1 - p (\theta_l)) p (\theta_d)\}^2}
\]

\[
\times \left[ p' (\theta_l) (1 - p (\theta_d)) + (1 - p (\theta_l)) p' (\theta_d) \times \frac{\kappa \beta \eta p' (\theta_l) (1 - p (\theta_d))}{\Phi (\theta_d, \theta_l)} \right]
\]

\[
= - \left( \frac{d\theta_l}{d\phi} \right) \times \frac{1}{\{\delta + p (\theta_l) + (1 - p (\theta_l)) p (\theta_d)\}^2}
\]

\[
\times \frac{p' (\theta_l) (1 - p (\theta_d)) q' (\theta_d) (1 - \eta) (y - b)}{\Phi (\theta_d, \theta_l)}
\]

< 0,

because of the properties of the matching function, \( q' (\theta) < 0 \) and \( p' (\theta) > 0 \). In summary,

\[
\frac{d\text{ur}^0}{d\phi} < 0 \quad \text{and} \quad \frac{d\text{ur}^1}{d\phi} < 0.
\]

Now we turn to the aggregate unemployment rate. In aggregate level, the total number of unemployed households is

\[
2 (u^0 + u^1) = 2 \left[ \frac{\delta \phi}{p (\theta_l) + \delta} + \frac{\delta (0.5 - \phi)}{\delta + p (\theta_l) + (1 - p (\theta_l)) p (\theta_d)} \right]
\]

By taking the derivative with respect to the fraction of settlers, we can characterize two
distinct factors affecting the unemployment rates.

\[
\frac{d\left(u^0 + u^1\right)}{d\phi} = \frac{\delta}{\delta + p(\theta_l)} - \frac{\delta}{\delta + p(\theta_l) + \left(1 - p(\theta_l)\right)p(\theta_d)}
\]

\[
- p'(\theta_l) \frac{d\theta_l}{d\phi} \left[\frac{\delta \phi}{\{\delta + p(\theta_l)\}^2} + \frac{\delta (0.5 - \phi) \left(1 - p(\theta_l)\right)}{\{\delta + p(\theta_l) + \left(1 - p(\theta_l)\right)p(\theta_d)\}^2}\right]
\]

\[
- p'(\theta_d) \left(1 - p(\theta_l)\right) \frac{d\theta_d}{d\theta_l} \frac{d\theta_l}{d\phi} \left[\frac{\delta (0.5 - \phi)}{\{\delta + p(\theta_l) + \left(1 - p(\theta_l)\right)p(\theta_d)\}^2}\right].
\]

The first line of the equation captures the direct effect from the change in composition of household types, and the bottom two lines captures the general equilibrium effect in both local and distant labor markets. It is obvious to show that the composition effect is positive:

\[
\frac{\delta}{\delta + p(\theta_l)} - \frac{\delta}{\delta + p(\theta_l) + \left(1 - p(\theta_l)\right)p(\theta_d)} > 0. \tag{45}
\]

We can verify that the general equilibrium effect, represented by the last two terms in the above equation (44), is negative:

\[
- p'(\theta_l) \frac{d\theta_l}{d\phi} \left[\frac{\delta \phi}{\{\delta + p(\theta_l)\}^2} + \frac{\delta (0.5 - \phi) \left(1 - p(\theta_l)\right)}{\{\delta + p(\theta_l) + \left(1 - p(\theta_l)\right)p(\theta_d)\}^2}\right]
\]

\[
- p'(\theta_d) \left(1 - p(\theta_l)\right) \frac{d\theta_d}{d\theta_l} \frac{d\theta_l}{d\phi} \left[\frac{\delta (0.5 - \phi)}{\{\delta + p(\theta_l) + \left(1 - p(\theta_l)\right)p(\theta_d)\}^2}\right] < 0. \tag{46}
\]
because

\[
\begin{align*}
&- p'(\theta_l) \frac{d\theta_l}{d\phi} \left[ \frac{\delta \phi}{\{\delta + p(\theta_l)\}^2} + \frac{\delta (0.5 - \phi) (1 - p(\theta_d))}{\{\delta + p(\theta_l) + (1 - p(\theta_l)) p(\theta_d)\}^2} \right] \\
&- p'(\theta_d) (1 - p(\theta_l)) \frac{d\theta_d}{d\phi} \frac{\delta (0.5 - \phi)}{\{\delta + p(\theta_l) + (1 - p(\theta_l)) p(\theta_d)\}^2} \\
&= - \delta p'(\theta_l) \frac{d\theta_l}{d\phi} \\
&\times \left[ \frac{\phi}{\{\delta + p(\theta_l)\}^2} + \frac{(0.5 - \phi) (1 - p(\theta_d))}{\{\delta + p(\theta_l) + (1 - p(\theta_l)) p(\theta_d)\}^2} \times \frac{q'(\theta_d) (1 - \eta) (y - b)}{\Phi(\theta_d, \theta_l)} \right].
\end{align*}
\]

The aggregate unemployment increases if the composition effect dominates the general equilibrium effect.

### B.5 Efficiency of Decentralized Equilibrium

So far, we have studied how the market equilibrium varies when there is change in composition of settlers. In this section, we define and solve a social planner’s problem and compare the solution to the decentralized economy to understand the relation between the allocation efficiency of the market outcome and the population composition. The social planner optimally chooses the market tightness functions for two distinct markets. In the local labor market, social planner is not able to distinguish two different types of households ex-ante as the firms in the decentralized economy.

\[
W(u^s, u^n) = \max_{\theta_l, \theta_d} b(u^s + u^n) + y (0.5 - u^s - u^n) \\
+ \beta \{ - \kappa \theta_l (u^s + u^n) - \kappa \theta_d (1 - p(\theta_l)) u^n + W(\hat{u}^s, \hat{u}^n) \}
\]

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where

\[
\hat{u}^s = (1 - p(\theta_l))u^s + \delta(\phi - u^s)
\]

\[
\hat{u}^n = (1 - p(\theta_l))(1 - p(\theta_d))u^n + \delta(0.5 - \phi - u^n).
\]

The market tightness in the local labor market affects the both groups of households, but the distant labor market tightness affects only the mobile households who didn’t find jobs in the first labor market. From the law of motion of unemployed workers for both types,

\[
\kappa = -p'(\theta_l)\left[\frac{u^s}{u^s + (1 - \theta_dp'(\theta_l))u^n}\frac{\partial W}{\partial u^s} + \frac{u^n(1 - p(\theta_d))}{u^s + (1 - \theta_dp'(\theta_l))u^n}\frac{\partial W}{\partial u^n}\right]
\]

\[
\kappa = -p'(\theta_d)\frac{\partial W}{\partial u^n}.
\]

In the local market, the expected gain from increasing a job finding rate by \(p'(\theta_l)\) is the weighted average of gains from having additional workers by types. Since \(p(\theta_d)\) fraction of unemployed nomads become employed in the distant job search, the effective number of additional nomad workers matched in the local labor market is \((1 - p(\theta_d))u^n\), not \(u^n\). Furthermore, considering the fact that there is a distant market for nomads in the second stage, the social planner acts as if there are less unemployed nomads in the local market \(((1 - \theta_dp'(\theta_l))u^n)\), as opposed to the firms in the decentralized market \((u^n)\). Applying the Envelope Theorem, we can analytically solve the value of each additional match as the
following:

\[ R_n \equiv -\frac{\partial W}{\partial u^n} = \frac{y - b + \beta \kappa \theta_l + \beta \kappa \theta_d (1 - p(\theta_l))}{1 - \beta \{(1 - p(\theta_l))(1 - p(\theta_d)) - \delta\}} \]

\[ R_s \equiv -\frac{\partial W}{\partial u^s} = \frac{y - b + \beta \kappa \theta_l}{1 - \beta \{(1 - p(\theta_l)) - \delta\}}. \]

We first set \( \phi = 0 \) and study how the efficiency of equilibrium changes with remote-job search. In this case, the first-order conditions of the social planner’s problem at the steady state are simplified as following:

\[ \kappa = -p'(\theta_l) \left( \frac{1 - p(\theta_d)}{1 - \theta_d p'(\theta_l)} \right) \frac{\partial W}{\partial u^n} \]

\[ \kappa = -p'(\theta_d) \frac{\partial W}{\partial u^n}. \]

The optimality condition can be rewritten as

\[ \frac{p'(\theta_d)}{p'(\theta_l) (1 - p(\theta_d))} = \frac{1}{1 - \theta_d p'(\theta_l)}. \]

Now we compare the solution of the social planner’s problem to the equilibrium of decentralized market. Define

\[ \omega \equiv \frac{1 - p(\theta_d)}{1 - \theta_d p'(\theta_l)} = \frac{p'(\theta_d)}{p'(\theta_l)}. \]

\[ \kappa = \frac{p'(\theta^S_{SP}) (y - b)}{1 - \beta \left( 1 - \delta - \left( 1 - \frac{p'(\theta^S_{SP})}{p(\theta^S_{SP})} \right) p(\theta^S_{SP}) - (1 - p(\theta^S_{SP})) \left( 1 - \frac{p'(\theta^S_{SP})}{q(\theta^S_{SP})} \right) p(\theta^S_{SP}) \right)} \]

\[ \kappa = \frac{\omega p'(\theta^S_{SP}) (y - b)}{1 - \beta \left( 1 - \delta - \left( 1 - \frac{\omega p'(\theta^S_{SP})}{q(\theta^S_{SP})} \right) p(\theta^S_{SP}) - (1 - p(\theta^S_{SP})) \left( 1 - \frac{\omega p'(\theta^S_{SP})}{q(\theta^S_{SP})} \right) p(\theta^S_{SP}) \right)}. \]

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Recall the free entry conditions in the decentralized market with $\phi = 0$ are

$$\kappa = \frac{q(\theta_d) (1 - \eta) (y - b)}{1 - \beta [(1 - \delta) - \eta p(\theta_l) - (1 - \eta p(\theta_l)) \eta p(\theta_d)]}$$

$$\kappa = \frac{q(\theta_l) (1 - \eta) (1 - \eta p(\theta_d)) (y - b)}{1 - \beta [(1 - \delta) - \eta p(\theta_l) - (1 - \eta p(\theta_l)) \eta p(\theta_d)]}.$$ 

It is straightforward that the Hosios condition does not apply in this economy. When the bargaining power is set equal to $p'(\theta_d) = q(\theta_d) (1 - \eta)$ or

$$1 - \frac{p'(\theta_d)}{q(\theta_d)} = \eta,$$

the optimality condition of the planner’s problem in distant market becomes

$$\kappa = \frac{q(\theta_{SP}^d) (1 - \eta) (y - b)}{1 - \beta [(1 - \delta) - \eta p(\theta_{SP}^d) - (1 - \eta p(\theta_{SP}^d)) \eta p(\theta_{SP}^d)]}$$

$$\neq \frac{q(\theta_{SP}^d) (1 - \eta) (y - b)}{1 - \beta [(1 - \delta) - \eta p(\theta_{SP}^d) - (1 - \eta p(\theta_{SP}^d)) \eta p(\theta_{SP}^d)]}.$$ 

Similarly, if $\omega p'(\theta_l) = q(\theta_l) (1 - \eta)$ or

$$1 - \frac{\omega p'(\theta_l)}{q(\theta_l)} = 1 - \frac{p'(\theta_d)}{q(\theta_l)} = \eta,$$

$$\kappa = \frac{q(\theta_{SP}^l) (1 - \eta) (y - b)}{1 - \beta [(1 - \delta) - \eta q(\theta_{SP}^l) - (1 - \eta q(\theta_{SP}^l)) \eta p(\theta_{SP}^l)]}$$

$$\neq \frac{q(\theta_{SP}^l) (1 - \eta) (y - b)}{1 - \beta [(1 - \delta) - \eta q(\theta_{SP}^l) - (1 - \eta q(\theta_{SP}^l)) \eta p(\theta_{SP}^l)]}.$$ 

Even after correcting the search externality by setting the bargaining share of each parties
to be consistent with their externality in each labor market, the optimal outcome cannot be implemented in decentralized economy. Workers use the existence of additional search opportunity in the other location when they negotiate their wages, and it makes the match surplus functions be dependent to $1 - \eta_p(\theta_l)$ and $1 - \eta p(\theta_d)$.

**B.6 A Model with Alternative Labor Market Structure**

We introduce two distinct local labor markets, local market 1 and local market 2. All the immobile workers participate in the local labor market 1 whereas mobile individuals split into two local labor markets. $1 - \rho$ fraction of mobile workers search along with immobile workers in the local labor market 1 and the other $\rho$ fraction of mobile workers search in a segregated local labor market 2. For simplicity, $\rho$ is assumed to be i.i.d.

Under this modified labor market structure, the value functions of each type are given by:

\[
U^s = b + \beta \{ p(\theta_1^1) W^s(w^s) + (1 - p(\theta_1^1)) U^s \} \\
U^n = b + \beta \{ (1 - \delta) p(\theta_1^1) W^n(w^n) + \delta p(\theta_2^1) W^n(w^n) \}
\]

\[
W^s(w) = w + \beta \{ (1 - \delta) W^s(w^s) + \delta U^s \} \\
W^n(w) = w + \beta \{ (1 - \delta) W^n(w^n) + \delta U^n \}
\]

The value of a firm with a matched worker at wage $w$ collects $y - w$ every period until the
match dissolves with exogenous probability $\delta$.

$$J(w) = y - w + \beta (1 - \delta) J(w).$$

The wage of a match is determined by Nash Bargaining after the labor market searches are done.

$$w^i = \arg\max \{ W^i(w) - U^i \}^\eta J(w)^{1-\eta}.$$

Under the Nash bargaining assumption, a firm and a worker split the match surplus proportionally to their bargaining power. The match surplus of settler is given by:

$$S^s(\theta^1_l, \theta^2_l, \theta_d) \equiv J(w) + W^s(w) - U^s = \frac{y - b}{1 - \beta \{ (1 - \delta) - \eta p(\theta^1_l) \}}.$$

Similarly, the surplus of a match with a nomad is as follows:

$$S^n(\theta^1_l, \theta^2_l, \theta_d) \equiv J(w) + W^n(w) - U^n = \frac{y - b}{1 - \beta \{ (1 - \delta) - \eta \{ (1 - \rho) p(\theta^1_l) + \rho p(\theta^2_l) + (1 - (1 - \rho) p(\theta^1_l) - \rho p(\theta^2_l)) p(\theta_d) \} \}}.$$

Under the modified market structure, there are three labor markets in each location. We define $\theta^1_l$ and $\theta^2_l$ as the market tightness of local labor market 1 and 2, respectively. The market tightness for a distant labor market is denoted by $\theta_d$. For each labor market, we assume the free entry condition holds. Therefore, in equilibrium the expected return of
posting a vacancy is equal to the posting cost, $\kappa$.

\begin{align*}
\kappa & = q(\theta_d) J(w^n) \\
\kappa & = q(\theta^2_l) J(w^n) \\
\kappa & = q(\theta^1_l) \left\{ \frac{u^s}{(1-\rho)u^n + u^s} J(w^s) + \frac{(1-\rho)u^n}{(1-\rho)u^n + u^s} J(w^n) \right\}.
\end{align*}

\section{Data}

This section describes the details of the data sets used in this paper. We use micro data from the Annual Social and Economic Supplement to the Current Population Survey (March CPS) and Survey of Income and Program Participation (SIPP), and data on population flows aggregated at the state level from the IRS tax records. When using micro data, in order to focus on migration that is not motivated by changes in schooling (for example, college attendance and graduation) or retirement, we restrict the sample to nonmilitary/civilian individuals who are between 25 and 60 years of age at the time of the survey. March CPS is obtained from the Integrated Public Use Micro data Series (King et al. (2010)).\footnote{The data can be obtained on \url{https://cps.ipums.org/cps/}.} After 1996, we exclude observations with imputed migration data to avoid complications arising due to changes in CPS imputation procedures.\footnote{See Kaplan and Schulhofer-Wohl (2012) for a detailed explanation.}
Table 22
SUMMARY STATISTICS FOR THE SIPP SAMPLE

<table>
<thead>
<tr>
<th>Variable</th>
<th>Statistic</th>
</tr>
</thead>
<tbody>
<tr>
<td># Individuals</td>
<td>4200900</td>
</tr>
<tr>
<td>Married (%)</td>
<td>60.6</td>
</tr>
<tr>
<td>Holding a college degree (%)</td>
<td>26.6</td>
</tr>
<tr>
<td>In the labor force (%)</td>
<td>86.6</td>
</tr>
<tr>
<td>Employed (%)</td>
<td>81.7</td>
</tr>
<tr>
<td>Mean Age</td>
<td>41.7</td>
</tr>
</tbody>
</table>

Note: This table shows some summary statistics of the SIPP sample that is used in the paper. Prior to 1996, we impute college attainment by years of schooling. After 1996, we observe the conferral of the degree. A person is counted as employed if they report being continuously employed for a month. A person is counted in the labor force if he is either employed or reports to having looked for a job at least one week.

We provide more details about the SIPP as it is less commonly used in the migration literature. SIPP is a large representative sample of households interviewed every four months (a “wave”) for two to four years. The first panel begins in 1984, and a new cohort is added around the time when the previous cohort exits. The latest wave that we use was started in 2004, and contains data for years 2003-2007. We have around 4.2 million individual-wave observations between 1984 and 2007. Migration information can be constructed in all but the first wave of each panel. Some summary statistics are presented in Appendix C. As explained in Aaronson and Davis (2011), SIPP is useful to study migration behavior because it tracks households when they move to different addresses, and because it contains various demographic information.

We also use data at the state level on population flows, population, personal income, homeownership, and unemployment. Data on population flows come from tax records and are constructed by the Internal Revenue Service. Flows are annual and refer to migration

\footnote{Two exceptions we are aware of are Aaronson and Davis (2011) and Guler and Taskin (2012).}

\footnote{Data can be downloaded from http://thedataweb.rm.census.gov/ftp/sipp_ftp.html.}
over the period between two consecutive Aprils. IRS reports for each state inflow and outflow data in two units: “returns” and “personal exemptions.” The returns data measures the number of households that move, and the personal exemptions data approximates the population.\footnote{Data from 2004 to 2012 are available for free on the IRS website on http://www.irs.gov/uac/SOI-Tax-Stats-Migration-Data. This discussion is based on Davis et al. (2010) and Karahan and Rhee (2013), who used county-county population flows to construct MSA-MSA population flows.} We use personal exemptions. Census Bureau provides annual homeownership rates and population estimates.\footnote{Population estimates for the period 1980-2012 are available on ... Homeownership rates for states for the period 1984-2011 are obtained from Table 15 on http://www.census.gov/housing/hvs/data/ann11ind.html.} Data on personal income and unemployment are obtained from the Regional Economic Accounts at the Bureau of Economic Analysis and Local Area Unemployment Statistics at the Bureau of Labor Statistics, respectively.\footnote{http://www.bea.gov/iTable/index_regional.cfm and ftp://ftp.bls.gov/pub/time.series/la/}

D Additional Results: The Quantitative Model

D.1 Properties of the Cut-offs

1. $\Sigma_A$ is increasing with respect to $\epsilon$.

2. $\Sigma_B$ is decreasing with respect to $\epsilon$.

3. $\epsilon_{A,l} < \epsilon_{A,d}$

4. $\epsilon_{B,d} < \epsilon_{B,l}$

5. $\epsilon_l^A < \epsilon_l^B$

Given the above properties of the cutoffs, we know there are potentially five possible orders of four cutoffs, $\epsilon_{A,l}, \epsilon_{B,l}, \epsilon_{A,d}$, and $\epsilon_{B,d}$. For a given order of cutoff values, there are five
possible migration patterns. We derive analytical solution of these functions for each possible orderings and use them for computation.

1. Order 1: $\epsilon_{B,d}^n < \epsilon_{A,l}^n < \epsilon_{B,l}^n < \epsilon_{A,d}^n$

2. Order 2: $\epsilon_{B,d}^n < \epsilon_{A,l}^n < \epsilon_{A,d}^n < \epsilon_{B,l}^n$

3. Order 3: $\epsilon_{A,l}^n < \epsilon_{B,d}^n < \epsilon_{B,l}^n < \epsilon_{A,d}^n$

4. Order 4: $\epsilon_{A,l}^n < \epsilon_{B,d}^n < \epsilon_{A,d}^n < \epsilon_{B,l}^n$

5. Order 5: $\epsilon_{A,l}^n < \epsilon_{A,d}^n < \epsilon_{B,d}^n < \epsilon_{B,l}^n$
D.2 Steady-State Unemployment

The equations below describe the law of motion for the measure of employed and unemployed workers of all types in both locations:

\[
\begin{align*}
\epsilon_{t+1}^A (\epsilon, \mu) &= \epsilon_t^A (\epsilon, \mu) - \delta \epsilon_t^A (\epsilon, \mu) \mathbb{I}_{\{\epsilon \leq \epsilon_t^A (\mu)\}} + u_t^B (\epsilon, \mu) \mathbb{I}_{\{\epsilon \geq \epsilon_t^B (\mu)\}} \\
&\quad - p (\theta_t^A) \left( u_t^A (\epsilon, \mu) - u_t^A (\epsilon, \mu) \mathbb{I}_{\{\epsilon \leq \epsilon_t^A (\mu)\}} + u_t^B (\epsilon, \mu) \mathbb{I}_{\{\epsilon \geq \epsilon_t^B (\mu)\}} \right) \\
&\quad - p (\theta_t^B) \left( 1 - p (\theta_t^A) \right) \times \left( u_t^A (\epsilon, \mu) - u_t^A (\epsilon, \mu) \mathbb{I}_{\{\epsilon \leq \epsilon_t^A (\mu)\}} + u_t^B (\epsilon, \mu) \mathbb{I}_{\{\epsilon \geq \epsilon_t^B (\mu)\}} \right) \mathbb{I}_{\{\epsilon \leq \epsilon_t^A (\mu)\}} \\
\end{align*}
\]

\[
\begin{align*}
u_{t+1}^A (\epsilon, \mu) &= u_t^A (\epsilon, \mu) + \delta u_t^A (\epsilon, \mu) - u_t^A (\epsilon, \mu) \mathbb{I}_{\{\epsilon \leq \epsilon_t^A (\mu)\}} + u_t^B (\epsilon, \mu) \mathbb{I}_{\{\epsilon \geq \epsilon_t^B (\mu)\}} \\
&\quad - p (\theta_t^B) \left( u_t^B (\epsilon, \mu) + u_t^A (\epsilon, \mu) \mathbb{I}_{\{\epsilon \leq \epsilon_t^A (\mu)\}} - u_t^B (\epsilon, \mu) \mathbb{I}_{\{\epsilon \geq \epsilon_t^B (\mu)\}} \right) \\
&\quad - p (\theta_t^B) \left( 1 - p (\theta_t^A) \right) \times \left( u_t^B (\epsilon, \mu) + u_t^A (\epsilon, \mu) \mathbb{I}_{\{\epsilon \leq \epsilon_t^A (\mu)\}} - u_t^B (\epsilon, \mu) \mathbb{I}_{\{\epsilon \geq \epsilon_t^B (\mu)\}} \right) \mathbb{I}_{\{\epsilon \geq \epsilon_t^B (\mu)\}} \\
\end{align*}
\]
\[ e_{t+1}^B (\epsilon, \mu) = e_t^B (\epsilon, \mu) - \delta e_t^B (\epsilon, \mu) \]

\[ + p(\theta_t^B) \left( u_t^B (\epsilon, \mu) + u_t^A (\epsilon, \mu) I\{ \epsilon \leq \epsilon_t^A (\mu) \} - u_t^B (\epsilon, \mu) I\{ \epsilon \geq \epsilon_t^B (\mu) \} \right) \]

\[ + p(\theta_t^B) \left( 1 - p(\theta_t^A) \right) \]

\[ \times \left( u_t^A (\epsilon, \mu) - u_t^A (\epsilon, \mu) I\{ \epsilon \leq \epsilon_t^A (\mu) \} + u_t^B (\epsilon, \mu) I\{ \epsilon \geq \epsilon_t^B (\mu) \} \right), \]

Aggregate unemployment in location \( j \) is simply the integral of the type-specific unemployment \( u_t^j (\epsilon, \mu) \) over the distribution of \((\epsilon, \mu)\) in that location. For a case where \( \epsilon_d^B < \epsilon_t^A < \epsilon_t^B < \epsilon_d^A \), we derive the steady state measure of workers of each types are defined as follow.

Unemployment for other possible cases can be derived in similar way.

1. \( \epsilon > \epsilon_d^A \) : \( mo^A = mo^B = u_B = e_B = 0 \) and

\[ u_A = \frac{\delta f (\epsilon, \mu)}{p(\theta_t^A) + \delta} \]

\[ e_A = \frac{p(\theta_t^A) \delta f (\epsilon, \mu)}{\delta \{ p(\theta_t^A) + \delta \}} \]

in steady state.

2. \( \epsilon \in [\epsilon_d^B, \epsilon_d^A] \) : \( mo^A = 0 \) because \( \epsilon \geq \epsilon_d^B > \epsilon_d^A \). All the unemployed in B moves to A in migration stage because \( \epsilon \geq \epsilon_d^B \). Thus \( mo_t^B = u_t^B \).

\[ e^A = \frac{p_t^A f (\epsilon, \mu)}{\delta + \{ p_t^A + p_d^B (1 - p_t^A) \}} \]

\[ e^B = \frac{p_d^B (1 - p_t^A) f (\epsilon, \mu)}{\delta + \{ p_t^A + p_d^B (1 - p_t^A) \}} \]

\[ u^A = \frac{\delta f (\epsilon, \mu) \{ 1 - p_d^B (1 - p_t^A) \}}{\delta + \{ p_t^A + p_d^B (1 - p_t^A) \}} \]

\[ u^B = \frac{\delta p_d^B (1 - p_t^A) f (\epsilon, \mu)}{\delta + \{ p_t^A + p_d^B (1 - p_t^A) \}} \]
in steady state.

3. \( \epsilon \in [\epsilon_t^A, \epsilon_t^B] \): Whenever they are unemployed, they stay the place. Therefore, \( mo^A = mo^B = 0 \).

\[
\begin{align*}
    u_A &= \frac{\delta p_d^A (1 - p_t^B) f(\epsilon, \mu)}{p_d^A (1 - p_t^B) (\delta + p_t^A) + p_d^B (1 - p_t^B) (\delta + p_t^B) + 2 p_d^A (1 - p_t^B) p_d^B (1 - p_t^A)} \\
    u_B &= \frac{\delta p_d^B (1 - p_t^A) f(\epsilon, \mu)}{p_d^A (1 - p_t^B) (\delta + p_t^A) + p_d^B (1 - p_t^B) (\delta + p_t^B) + 2 p_d^A (1 - p_t^B) p_d^B (1 - p_t^A)} \\
    e_A &= \frac{\{ p_t^A + p_d^A (1 - p_t^B) \} p_d^A (1 - p_t^A) f(\epsilon, \mu)}{p_d^A (1 - p_t^B) (\delta + p_t^A) + p_d^B (1 - p_t^B) (\delta + p_t^B) + 2 p_d^A (1 - p_t^B) p_d^B (1 - p_t^A)} \\
    e_B &= \frac{\{ p_t^B + p_d^B (1 - p_t^B) \} p_d^B (1 - p_t^A) f(\epsilon, \mu)}{p_d^A (1 - p_t^B) (\delta + p_t^A) + p_d^B (1 - p_t^B) (\delta + p_t^B) + 2 p_d^A (1 - p_t^B) p_d^B (1 - p_t^A)}.
\end{align*}
\]

4. \( \epsilon \in [\epsilon_d^B, \epsilon_A^l] \): \( mo^A = u_A^l \) and \( mo^B = 0 \).

\[
\begin{align*}
    e_A &= \frac{p_d^A (1 - p_t^B) f(\epsilon, \mu)}{\delta + \{ p_t^B + p_d^A (1 - p_t^B) \}} \\
    e_B &= \frac{\delta f(\epsilon, \mu) \{ 1 - p_d^B (1 - p_t^B) \}}{\delta + \{ p_t^B + p_d^A (1 - p_t^B) \}} \\
    u_A &= \frac{\delta p_d^A (1 - p_t^B) f(\epsilon, \mu)}{\delta + \{ p_t^B + p_d^A (1 - p_t^B) \}} \\
    u_B &= \frac{\delta f(\epsilon, \mu) \{ 1 - p_d^B (1 - p_t^B) \}}{\delta + \{ p_t^B + p_d^A (1 - p_t^B) \}}.
\end{align*}
\]

5. \( \epsilon < \epsilon_d^B \): \( mo^A = mo^B = u_A = e_A = 0 \) and

\[
\begin{align*}
    u_B &= \frac{\delta f(\epsilon, \mu)}{p(\theta_t^B) + \delta} \\
    e_B &= \frac{p(\theta_t^B) \delta f(\epsilon, \mu)}{\delta \{ p(\theta_t^B) + \delta \}}.
\end{align*}
\]
D.3 Match Surplus Functions for Each Migration Patterns

For each possible ordering of cutoff values, we analytically find the match surplus functions (or a system of equations of them) and use the derivation for computation. In this section we derive the match surplus functions for the first order ($\epsilon_{B,d}^n < \epsilon_{A,l}^n < \epsilon_{B,l}^n < \epsilon_{A,d}^n$). Surplus functions for other possible cases can be derived in similar way.

1. $\epsilon > \epsilon_{d, A}^A$

   (a) $S_l^A = \frac{y - b}{1 - \beta(1 - \delta) + \beta np(\theta_A^d)}$

   (b) $S_l^B = \frac{y - 2\epsilon(1 - \beta)\beta\mu - b(\theta_A^d)}{1 - \beta(1 - \delta) + \beta np(\theta_A^d)} - p(\theta_A^l) \eta S_A^A$

   (c) $S_d^A = 2\epsilon - (1 - \beta) \mu + \frac{y - b}{1 - \beta(1 - \delta) + \beta np(\theta_A^d)}$

   (d) $S_d^B = \frac{y - b}{1 - \beta(1 - \delta) + \beta np(\theta_A^d)} - \mu - \frac{2\epsilon(1 + \beta\delta)\beta\mu}{1 - \beta(1 - \delta)}$

   (e) $\Sigma_A = \frac{1}{1 - \beta} \left[ b + \epsilon + p(\theta_A^d)\eta(y - b) \right]$

   (f) $\Sigma_B = b - \epsilon + \beta(\Sigma_A - \mu) + p(\theta_A^d) \eta S_A^A + p(\theta_B^l) \eta S_l^B$

2. $\epsilon \in [\epsilon_{B,l}, \epsilon_{A,d}]$

   (a) $S_l^A = \frac{y - b - (1 + \beta)\mu - b(\theta_A^d)}{1 - \beta(1 - \delta) + \beta np(\theta_A^d)}\eta S_A^B$

   (b) $S_l^B = \frac{1}{1 - \beta(1 - \delta)}$

   $\times \left[ y - 2\epsilon(1 - \beta)\beta\mu - b(\theta_A^d) \eta S_A^A - \beta p(\theta_A^d) \eta S_A^B - (1 - \beta(1 - \delta))p(\theta_A^d) \eta S_A^A \right]$

   (c) $S_d^A = 2\epsilon - (1 - \beta) \mu + \frac{y - b - \beta p(\theta_A^d)\eta S_A^A - \beta p(\theta_A^d)\eta S_A^B}{1 - \beta(1 - \delta)}$

   (d) $S_d^B = \frac{y - 2(1 + \beta)\epsilon(1 - \beta(1 - \delta))\mu - b(\theta_A^d)}{1 - \beta(1 - \delta) + \beta np(\theta_A^d)}\eta S_A^A$

   (e) $\Sigma_A = \frac{b + \epsilon + p(\theta_A^d)\eta S_A^B + p(\theta_A^d)\eta S_A^A}{1 - \beta}$

   (f) $\Sigma_B = b - \epsilon + \beta(\Sigma_A - \mu) + p(\theta_A^d) \eta S_A^A + p(\theta_B^l) \eta S_l^B$
3. $\epsilon \in [\epsilon_{A,l}, \epsilon_{B,l}]
\begin{align*}
(a) \quad S_t^A &= \frac{y-b-(1+\beta)\mu (\theta^B_d)\eta S^B_d}{1-\beta(1-\delta)} - p(\theta^B_d)\eta S^B_d \\
(b) \quad S_t^B &= \frac{y-b-(1+\beta)\mu (\theta^A_d)\eta S^A_d}{1-\beta(1-\delta)} \\
(c) \quad S_d^A &= \frac{y+2\epsilon-b-\{1-\beta(1-\delta)\} \mu + \beta \mu (U^A - U^B) - \beta p(\theta^B_d)\eta S^B_d}{1-\beta(1-\delta)+\beta \mu p(\theta^B_d)} \\
(d) \quad S_d^B &= \frac{y+2\epsilon-b-\{1-\beta(1-\delta)\} \mu - \beta \mu (U^A - U^B) - \beta p(\theta^A_d)\eta S^A_d}{1-\beta(1-\delta)+\beta \mu p(\theta^B_d)} \\
(e) \quad \Sigma_A &= \frac{b+\epsilon+p(\theta^B_d)\eta S^B_d + p(\theta^A_d)\eta S^A_d}{1-\beta} \\
(f) \quad \Sigma_B &= \frac{b-\epsilon+p(\theta^B_d)\eta S^B_d + p(\theta^A_d)\eta S^A_d}{1-\beta}
\end{align*}

4. $\epsilon \in [\epsilon_{B,d}, \epsilon_{A,l}]
\begin{align*}
(a) \quad S_t^A &= \frac{y-b+\beta \mu (1-\beta)+2\beta \epsilon-\beta p(\theta^B_d)\eta S^B_d-\beta p(\theta^A_d)\eta S^A_d}{1-\beta(1-\delta)} - p(\theta^B_d)\eta S^B_d \\
(b) \quad S_t^B &= \frac{y-b-(1+\beta)\mu (\theta^A_d)\eta S^A_d}{1-\beta(1-\delta)} \\
(c) \quad S_d^A &= \frac{y+2(1+\beta)\epsilon-\{1-\beta(1-\delta-\beta \delta)\} \mu - b-\beta p(\theta^B_d)\eta S^B_d}{1-\beta(1-\delta)+\beta \mu p(\theta^B_d)} \\
(d) \quad S_d^B &= -2\epsilon - (1-\beta) \mu + \frac{y-b-\beta p(\theta^A_d)\eta S^A_d-\beta p(\theta^B_d)\eta S^B_d}{1-\beta(1-\delta)} \\
(e) \quad \Sigma_A &= \frac{b+\epsilon+\beta (\Sigma_B - \mu) + p(\theta^B_d)\eta S^B_d (\epsilon, \mu) + p(\theta^A_d)\eta S^A_d (\epsilon, \mu)}{1-\beta} \\
(f) \quad \Sigma_B &= \frac{b-\epsilon+p(\theta^B_d)\eta S^B_d (\epsilon, \mu) + p(\theta^A_d)\eta S^A_d (\epsilon, \mu)}{1-\beta}
\end{align*}

5. $\epsilon < \epsilon_{B,d}
\begin{align*}
(a) \quad S_t^A &= \frac{y-b+2\beta \epsilon+(1-\beta)\beta \mu - \beta p(\theta^B_d)\eta S^B_d}{1-\beta(1-\delta)} - p(\theta^B_d)\eta S^B_d \\
(b) \quad S_t^B &= \frac{y-b}{1-\beta(1-\delta)+\beta \mu p(\theta^B_d)} \\
(c) \quad S_d^A &= \frac{1}{1-\beta(1-\delta)} \left[ y + 2 (1 + \beta \delta) \epsilon - \{1 - \beta (1 - \delta - \beta \delta)\} \mu - \frac{\beta p(\theta^B_d)\eta (y-b)}{1-\beta(1-\delta)+\beta \mu p(\theta^B_d)} \right] \\
(d) \quad S_d^B &= -2\epsilon - (1-\beta) \mu + \frac{y-b}{1-\beta(1-\delta)+\beta \mu p(\theta^B_d)}
\end{align*}
(e) $\Sigma_A = b + \epsilon + \beta (\Sigma_B - \mu) + p(\theta_d^B) \eta S^B_d + p(\theta_d^A) \eta S^A_d$

(f) $\Sigma_B = \frac{b - \epsilon}{1 - \beta} + \frac{p(\theta_d^A) \eta}{1 - \beta} \left[ \frac{y - b}{1 - \beta(1 - \delta) + \beta p(\theta_d^B)} \right]$ 

D.4 Overview of the Computational Algorithm

This section describes the details of the estimation used in this paper.

1. **Loop 1**: Guess a vector of the structural parameters $\Theta$.

   (a) **Loop 2**: Start with initial guess of market tightnesses, $\{\theta_i^j, \theta_i^d\}_{j \in \{A,B\}}$.

   i. For each type of workers ($i = 1, 2, \ldots, N$), assume a possible order of cutoffs and derive the match surplus functions

   $\left\{ S_{i,o}^{i,o} A, l, S_{i,o}^{i,o} B, l, S_{i,o}^{i,o} A, d, S_{i,o}^{i,o} B, d, \Sigma_{i,o}^A, \Sigma_{i,o}^B \right\}_{i \in \{1, 2, \ldots, N\}}^{o = 1, 2, 3, 4, 5}$

   for each case based on D.3.

   ii. Find the correct ordering of cutoffs, $\{\epsilon_i^i, \epsilon_i^j, \epsilon_i^d\}_{i \in \{1, 2, \ldots, N\}}$:

   A. For all five possible orderings, compute the exact cutoff values implied by the match surplus functions.

   \[
   \begin{align*}
   \Sigma_{i,o}^B \left( \epsilon_{i,o}^i, \mu_i \right) - \Sigma_{i,o}^A \left( \epsilon_{i,o}^i, \mu_i \right) & = \mu_i \\
   \Sigma_{i,o}^A \left( \epsilon_{i,o}^i, \mu_i \right) - \Sigma_{i,o}^B \left( \epsilon_{i,o}^i, \mu_i \right) & = \mu_i \\
   \theta_{i,o}^A \left( \epsilon_{i,o}^i, \mu_i \right) & = 0 \\
   \theta_{i,o}^B \left( \epsilon_{i,o}^i, \mu_i \right) & = 0.
   \end{align*}
   \]
B. Check if the computed cutoff values are consistent with the assumption of the ordering.

iii. Using the cutoff values and job finding probabilities, we compute the steady-state unemployment of each type in each location using D.2.

iv. Compute the distance from the free-entry condition of four labor markets.

v. Repeat Loop 2 with different initial guess until the free-entry conditions are satisfied.

(b) Simulate the economy and obtain long-run averages of model generated moments $M_i^{model}$.

(c) Compute $\sum \left( \frac{M_i^{model} - M_i^{data}}{M_i^{data}} \right)^2$ and end the Loop 1 if it satisfies the convergence criterion. Otherwise, return to 1.
Chapter IV

Appendix to Chapter 2

E Data Appendix

Annual output data at the MSA level are available at the Bureau of Economic Analysis (BEA) website for the period 2001–2009.\(^5\) We use real GDP by metropolitan area in millions of chained 2005 dollars (all industry total). Employment and unemployment data are taken from the Bureau of Labor Statistics (BLS). These variables are also available at monthly frequency. We construct a measure of local labor productivity for each MSA as the ratio of output to employment. Population data are taken from the Regional Economic Accounts of the Bureau of Economic Analysis (table CA1-3). These are available at http://www.bea.gov/regional/reis. Population numbers reported are midyear estimates. Quarterly data on house prices are obtained from the Federal Housing Finance Agency. We use all-transaction indexes (estimated using sales price and appraisal data). Annual estimates are computed as the average of quarterly observations.

Using county-county migration data based on tax return records of the Internal Revenue Service (IRS), we construct data on MSA-level population gross inflows, gross outflows, and net flows. These data are available from the IRS website for the period 2004–2009. For each year, IRS reports population inflows and outflows for all counties. These files report the origin and the destination counties and the number of migrants in two units: “returns” and “personal exemptions.” We follow Davis et al. (2010) and use the exemptions data, as these

\(^5\) http://bea.gov/regional/gdpmetro/
data approximate the migrant population as opposed to the number of households as in returns data.\footnote{For a more detailed description of the IRS data, see Davis et al. (2010).} Gross inflows into an MSA are computed as the sum of all inflows into any county in that MSA from any other county in other MSAs. Gross outflows are computed analogously. Inflow and outflow rates are computed as the ratio of flow to the population in that year. Finally, the net flow rate is defined as the difference between the gross inflow rate and the gross outflow rate.

\section*{F Existence of a Block-Recursive Equilibrium}

To prove proposition 2, we proceed in two steps. We first show that the functional equations and the corresponding free-entry conditions for firms and housing market intermediaries admit a solution, where the dependance of the value functions, market tightness functions, and the rental rate on the aggregate state is through exogenous shocks only. More formally, we show that there exists a set of market tightness functions \( \{\theta^i_1(w; \psi), \theta^i_2(p; \psi), \theta^i_b(p; \psi)\}_{i \in I} \), rental rate \( \{\rho^i(\psi)\}_{i \in I} \), and value functions of firms and housing market intermediaries \( \{J^i, L^i, R^i\}_{i \in I} \), which depend on \( \psi \) only through exogenous shocks \((z_i, \mu_i)_{i \in I}\), and not through any endogenous distribution \( \{\Gamma_i\}_{i \in I} \) or \( \{n_i\}_{i \in I} \). That is, we can reduce the state space \( \psi \) into exogenous shocks, \((z_i, \mu_i)_{i \in I}\). In the second stage, we collapse the problem of households into one big functional equation and show that it is a contraction. We also show that the functional equation maps the set of functions that do not depend on the endogenous distribution into the same set, provided that the market tightness functions and the rental rate are independent from the endogenous distribution as well. This shows that there is a solution to the problem of households that, together with the value functions, market tight-
ness functions, and rental rates of the first step, constitutes a block-recursive equilibrium of the economy.

### F.1 Market Tightness Functions

- Define \( \mathcal{J}(W \times Z) \) as the set of continuous and bounded functions \( J \) such that \( J : W \times Z \to \mathbb{R} \) and denote \( T_J \) as an operator associated with (27). It is easy to verify that \( T_J \) maps \( \mathcal{J} \) into \( \mathcal{J} \). Applying Blackwell’s sufficiency conditions, we can show that the operator \( T_J : \mathcal{J} \to \mathcal{J} \) is a contraction. Denote the fixed point of \( T_J \) as \( J^* \in \mathcal{J} \).

- Substituting \( J^* \) into the free-entry condition for the labor market, (29), we get the labor market tightness function \( \theta^*_l(w; \psi) \) as only a function of wage, and labor productivity shock \( z \):

\[
\theta^*_l(w; z) = \begin{cases} 
q_1^{-1} \left( \frac{k}{J^*(w; z)} \right) & \text{if } w \in W(z) \\
0 & \text{o/w}
\end{cases}
\]

- Similarly, we define \( \mathcal{R}(P_b \times M) \) as the set of continuous and bounded functions mapping \( P_b \times M \) to \( \mathbb{R} \), and \( \mathcal{L}(M) \) as the set of continuous and bounded functions from \( M \) to \( \mathbb{R} \). It is easy to show that the operator associated with (30) maps functions from \( \mathcal{R}(P_b \times M) \) into \( \mathcal{R}(P_b \times M) \) if \( \theta_b(\cdot) \) depends on \( \psi \) only through \( \mu \). Similarly, one can show that the operator associated with (33) maps functions from \( \mathcal{L}(M) \) into \( \mathcal{L}(M) \) if \( \psi_i(\cdot) \) depends on \( \psi \) only through \( \mu \). The standard contraction mapping argument can be applied to establish the existence of fixed points, \( R^* \) and \( L^* \), of operators (30) and (33).

\[57\] The assumption of full commitment to a constant wage contract of workers guarantees that \( \mathcal{J}(W \times Z) \) is a space of bounded and continuous functions.
Using the free-entry conditions for the housing markets, (32) and (34), and plugging them into the operators (30) and (33), respectively, one can solve for the market tightness functions $\theta^*_s(p; \mu)$ and $\theta^*_b(p; \mu)$:

$$
\theta^*_s(p; \mu) = \begin{cases} 
\pi^{-1}_s \left( \frac{\kappa}{\pi^s(p; \mu)} \right) & \text{if } p \in P_s(\mu) \\
0 & \text{o/w}
\end{cases}
$$

$$
\theta^*_b(p; \mu) = \begin{cases} 
\pi^{-1}_b \left( \frac{\mu - (1+r)^{-1}E_{\psi' | \psi}[\mu' | \mu]}{p - (1+r)^{-1}E_{\psi' | \psi}[\mu' | \mu]} \right) & \text{if } p \in P_b(\mu) \\
0 & \text{o/w}
\end{cases}
$$

Using the free-entry condition (35) in the operator (33), we get the rental rate of the economy $\rho(\psi)$ as a function of $\mu$.

$$
\rho^*(\mu) = \mu - \frac{1 - \gamma}{1 + r}E_{\psi' | \psi}[\mu' | \mu].
$$
F.2 Households’ Value Function

First, we reformulate the value functions of households as one function $V : I \times E \times \mathcal{W} \times A \times H \times \Xi \rightarrow \mathbb{R}$ such that

\[
V(i, e = 1, w, a, h = 1, \chi; \psi) = W^i(w, a, h_1, \chi; \psi)
\]

\[
V(i, e = 1, w, a, h = 0, \chi; \psi) = W^i(w, a, h_0, \chi; \psi)
\]

\[
V(i, e = 0, ; a, h = 1, \chi; \psi) = U^i(a, h_1, \chi; \psi)
\]

\[
V(i, e = 0, ; a, h = 0, \chi; \psi) = U^i(a, h_0, \chi; \psi).
\]

Using the above value function, $V$, we can define the labor market surplus function as

\[
\tilde{\Delta} (i, a, h; \psi) = \sum_{k=1}^{\tilde{T}} \mathbf{1}_{k=4} \left[ \max_{w \in W(z_i)} \pi_t(\theta^*_t(w; z_i)) \{ V(i, 1, w, a, h, \chi; \psi) - V(i, 0, w, a, h, \chi; \psi) \} \right]
\]

In similar manner, we define the option value of migration as

\[
\tilde{M}(i, a, h, \chi \psi) = (1 - h) \max_{j \in I} \tilde{\Delta}(j, a, h, \chi; \psi).
\]

We define a set of functions $\mathcal{V} : I \times E \times \mathcal{W} \times A \times H \times \Xi \times Z^I \times M^I \rightarrow \mathbb{R}$ and $T_V$
such that
\[(TV)(i, e, w, a, h; \{z_i, \mu_i\}_{i \in I}) = \sum_{k=1}^{I} 1_{k=i} \times \]
\[
\left\{(1 - e)(1 - h) \left\{ \max_{a' \geq a_0} u(c, l_0, h_0, \chi_i) + \beta \mathbb{E}_{\psi' | \psi} \left[ \tilde{M}(i, a', 0, \chi; \psi') \right] + \max_{p \in \mathcal{P}(\mu'), a' \geq \alpha p} \pi^*_h(p; \mu') \times \left\{ V(i, 0, w, a' - p, 1, \chi; \psi') + \Delta(i, a' - p, 1, \chi; \psi') - \tilde{M}(i, a', 0, \chi; \psi') \right\} \right\} \right\} + (1 - e) h \left\{ \max_{a' \geq a_1} u(c, l_0, h_1, \chi_i) + \beta \mathbb{E}_{\psi' | \psi} \left[ \tilde{M}(i, a', 1, \chi; \psi') \right] + \max_{p \in \mathcal{P}(\mu'), a' \geq \alpha p} \pi^*_h(p; \mu') \times \left\{ \tilde{M}(i, a' + p, 0, \chi; \psi') - \Delta(i, a', h, \chi; \psi') \right\} \right\} + e(1 - h) \left\{ \max_{a' \geq a_0} u(c, l_0, h_0, \chi_i) + \beta \mathbb{E}_{\psi' | \psi} \left[ (1 - \delta) \left\{ V(i, 1, w, a', 0, \chi; \psi') + \max_{p \in \mathcal{P}(\mu'), a' \geq \alpha p} \pi^*_h(p; \mu') \times \left\{ V(i, 1, w, a' - p, 1, \chi; \psi') - V(i, 1, w, a', 0, \chi; \psi') \right\} \right\} \right\} \right\} + ch \left\{ \max_{a' \geq a_1} u(c, l_0, h_1, \chi_i) + \beta \mathbb{E}_{\psi' | \psi} \left[ (1 - \delta) \left\{ V(i, 1, w, a', 1, \chi; \psi') + \max_{p \in \mathcal{P}(\mu'), a' \geq \alpha p} \pi^*_h(p; \mu') \times \left\{ V(i, 1, w, a' + p, 0, \chi; \psi') - V(i, 1, w, a', 1, \chi; \psi') \right\} \right\} \right\} \right\} + \tilde{\Delta}(i, a', 1, \chi; \psi') + \max_{p \in \mathcal{P}(\mu')} \pi^*_u(p; \mu') \left\{ \tilde{M}(i, a' + p, 0, \chi; \psi') - \tilde{\Delta}(i, a', 1, \chi; \psi') \right\} \right\} \right\},
\]
where
\[
a + ew + (1 - e)b = c + (1 - h)1_{k=i} \rho^*_1(\mu_i) + \frac{a'}{1 + r}.
\]

> We can show that the operator $TV$ maps a function from $\mathcal{V}$ into $\mathcal{V}$, where $\mathcal{V}$ is
the set of continuous and bounded functions on the appropriate domain, assuming a bounded and continuous utility function. From the definition of \( \tilde{\Delta}(\cdot) \) and \( \tilde{M}(\cdot) \), it is clear that if \( V \in \mathcal{V} \), then \( \tilde{\Delta}(i,a,h,\{\chi^i_t\}_{i \in I};\psi) = \tilde{\Delta}(i,a,h,\{\chi^i_t\}_{i \in I};z_i,\mu_i) \) and \( \tilde{M}(i,a,h,\{\chi^i_t\}_{i \in I};\psi) = \tilde{M}(i,a,h,\{\chi^i_t\}_{i \in I};z_i,\mu_i) \). Substituting \( \tilde{\Delta}(i,a,h,\{\chi^i_t\}_{i \in I};z_i,\mu_i) \) and \( \tilde{M}(i,a,h,\{\chi^i_t\}_{i \in I};z_i,\mu_i) \) into the definition of \( T_V \), we get \( T_V : \mathcal{V} \to \mathcal{V} \).

\( \triangleright \) \( \mathcal{V} \) is a complete metric space. Verifying Blackwell’s sufficiency conditions, one can easily show that \( T_V : \mathcal{V} \to \mathcal{V} \) is a contraction. Therefore, there exists a fixed point, \( V^* \in \mathcal{V} \). This is a solution to the household’s problem, and depends on the aggregate state only through \( \{z_i,\mu_i\}_{i \in I} \).

\[ G \quad \text{Computational Appendix—Not For Publication} \]

In this section, we describe the details of our computational procedure. We employ a nested fixed point algorithm to estimate the model and match model-generated moments to their empirical counterparts. In Section 9, we have shown that our model admits a block recursive equilibrium and the value functions, policy functions, and market tightness functions depend on the aggregate state of the economy \( \psi \), only through the exogenous stochastic shocks. This property ensures that we can solve for the equilibrium price schedules in the labor and housing markets without solving the problems of the households. The algorithm to solve for a block recursive equilibrium of the model consists of two stages that we explain below.

The state space is discretized.
G.1 Supply Side Problems

In the first stage, we solve the supply side problems to derive the market tightness functions. Recall that the value function of a firm matched with a worker in location $i$ is given by:

$$J^i(w; \psi) = z_i - w + \frac{1 - w}{1 + r} \mathbb{E} J^i(w; \psi').$$

We start with a guess for $J^i$ such that $J^i$ depends on $\psi$ only through the exogenous labor productivity shocks. The functional equation above is a contraction and has a unique fixed point. By construction, the fixed point is independent of the endogenous distribution of households across locations. Using the free-entry condition in the labor market presented below, we derive the corresponding labor market tightnesses in all the active submarkets:

$$\kappa = q_i \left[ \theta^i_l (w; \psi) \right] J^i (w; \psi) \text{ for all } w \text{ with } \theta^i_l (w; \psi) > 0.$$  

Similarly, we use the value functions of the intermediaries in the housing market together with the free-entry conditions to determine the rental rates and the price-probability schedules. Free entry in the rental market implies $\mu_i = L^i (\psi).$ Substituting this in the functional equation for $L^i,$ we obtain the following equation, which can be easily solved for $\rho^i (\psi):$

$$\mu_i = \rho^i (\psi) + \frac{1 - \gamma}{1 + r} \mathbb{E}_\mu \mu'_i.$$  

The free-entry condition in the market in which REMs are house buyers is given by:

$$k = q_s \left[ \theta^i_s (p; \psi) \right] \left[ R^i (\psi) - p \right] \text{ for all } p \text{ with } \theta^i_s (p; \psi) > 0.$$  

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Using the free entry condition that $\mu_i = R^i(\psi)$, we obtain a closed-form solution for $\theta^i_s$. In every active submarket ($\theta^i_s > 0$), the following relation holds:

$$\theta^i_s(p; \psi) = q_s^{-1} \left( \frac{k}{\mu_i - p} \right).$$

Lastly, recall that the value function of an REM with a house is given by:

$$R^i(\psi) = \max_p q_h \left[ \theta^i_b(p; \psi) \right] p + \frac{1 - q_b \left[ \theta^i_b(p; \psi) \right]}{1 + r} \mathbb{E} R^i(\psi').$$

Combining the free-entry condition, $\mu_i = R^i(\psi)$, and the fact that each submarket with $\theta^i_b(p; \psi) > 0$ should deliver the same value to REMs, we obtain the following expression

$$\mu_i = q_b \left[ \theta^i_b(p; \psi) \right] p + \frac{1 - q_b \left[ \theta^i_b(p; \psi) \right]}{1 + r} \mathbb{E} \mu^i' \text{ for all } p \text{ with } \theta^i_b(p; \psi) > 0,$$

and we can solve for $\theta^i_b(p; \psi)$.

### G.2 Household’s Problem

The second stage solves the various problems — consumption-saving, job search, migration decision, and housing transaction — that a household faces at various stages within a period.

We use standard value function iteration techniques to solve these problems. In solving every problem, the relevant choice set is discretized. We start with a guess for the value functions at the consumption-savings stage and solve the problems at the job search, migration and housing search stages. Using the policy rules obtained, we update our guess for the value functions at the consumption-savings stage according to the relevant Bellman equations. We
repeat the procedure until the value functions converge to the fixed point of the Bellman equation.

G.3 Overview of the Algorithm

Our procedure can be summarized as follows:

1. **Loop 1**—Guess a vector of the structural parameters $\Theta$.

   (a) Compute the rental market prices $p^i(\psi)$ and the price-probability schedules in the housing market $\theta^h_i(p;\psi)$ and $\theta^s_i(p;\psi)$.

   (b) **Loop 2**—Make an initial guess for the value functions of the household in the consumption-savings stage $U^i_0$ and $W^i_0$.

      i. Solve the job search problem for unemployed households and obtain $D^i$.

      ii. Solve the migration problem to obtain the decision rule for migration.

      iii. Solve the housing market problem for homeowners and renters to obtain the price posting behavior of participants.

      iv. Using the policy rules for job search, migration and house selling and buying behaviors, obtain $U^i_1$ and $W^i_1$ according to the relevant Bellman equations.

      v. If for each location $i$, $\|W^i_1 - W^i_0\| < \epsilon_V$ and $\|U^i_1 - U^i_0\| < \epsilon_V$, end Loop 2, otherwise set $U^i_0 = U^i_1$ and $V^i_0 = V^i_1$ and go to i.

2. Simulate the economy and check that all the free-entry conditions hold.

3. Obtain long-run averages of model generated moments $M^{MODEL}$.

4. If the moments satisfy $\sum \left( \frac{M^{MODEL}_i - M^{DATA}_i}{M^{DATA}_i} \right)^2$, end Loop 1. Otherwise, return to 1.
Bibliography


