

Labor Market Frictions and Moving Costs of the Employed and Unemployed*

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Abstract

Search frictions and switching costs may grant monopsony power to incumbent employers by reducing workers' outside options. This paper examines the role of labor market frictions and moving costs in explaining worker flows across labor markets in the US. Using data on non-college-educated workers from the Survey of Income and Program Participation (SIPP), I estimate a dynamic model of job search and location choice. I find that moving costs are substantial and that labor market frictions primarily inhibit the employed. For workers that have few within-location employment options, these frictions and switching costs may confer market power to incumbent employers.

JEL Classification: C35, E32, J22, J61, J64, R23

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1 Introduction

Migration is widely considered to be a key indicator of labor market health, for two reasons. First, it is understood to be the primary way by which local labor markets adjust to shocks (Topel, 1986; Blanchard and Katz, 1992; Yagan, 2014). Second, lower levels of migration may indicate a less competitive labor market: when workers are unable or unwilling to move, their outside options are diminished and employers can compensate them below their market value (Ransom, 1993; Fox, 2010), or recruit only within the local area (Karahan and Rhee, 2017).¹

In this paper, I develop and estimate a dynamic structural model that incorporates switching costs and search frictions—two commonly cited sources of monopsony power. In the model, workers choose labor markets in which to live, but face frictions in obtaining employment and costs to moving locations or entering or exiting the labor force. Moving costs depend on employment status and frictions depend on both employment status and local labor market conditions. These dimensions of migration have not yet been looked at in the literature. I use the model to compute moving costs by employment status and to examine workers’ relocation behavior in response to local labor market shocks or to a moving subsidy (e.g. Moretti, 2012; H.R. 2755, 2015). Workers’ willingness to move is informative of the extent of employers’ monopsony power through wage-setting or selective recruiting strategies. Because the model abstracts from within-location job switching, the results are most informative for workers who have relatively few employer options within a labor market. Examples include, but are not limited to, workers in natural resource extraction, broadcast journalism, or who work at ports of entry.

I study individual migration, employment, and labor force transitions across U.S. metropolitan areas over the period 2004–2013. My primary data source is confidential panel data collected by the Survey of Income and Program Participation (SIPP). My sample consists of prime-age white men who are not college educated. The large coverage of the SIPP allows me to observe many moves and to accurately observe the conditions of many local labor markets. The SIPP also contains detailed information on demographic characteristics and labor market experience.

The econometric model characterizes locations in three dimensions which enter workers’ utility functions and govern their decision making. The three dimensions are market and non-market amenities, expected earnings, and expected employment. Each worker has common preferences for a location’s market amenities (e.g. climate), but workers may value non-market amenities differently (e.g. proximity to family). Earnings and employment differ across workers based on differences in their observable and unobservable characteristics. For unobservables, workers are also classified into two discrete types which differ in terms of wages, employment, and switching costs.

¹Geography is an important part of monopsony power. See Bhaskar and To (1999); Bhaskar, Manning, and To (2002); Bhaskar and To (2003); and Staiger, Spetz, and Phibbs (2010) who examine multi-firm monopsony power through the lens of the canonical spatial models of Hotelling (1929) and Salop (1979).

The model specifies locational choice and labor supply as a discrete choice dynamic programming problem.² Search frictions enter the model in a reduced form, where those who choose to supply labor are assigned to employment according to a weighted lottery. The employment probability depends on local labor market conditions as well as the worker’s previous location decision and individual characteristics.³ In order to estimate the model, I utilize recent developments in the estimation of large-state-space dynamic discrete choice models. By making use of conditional choice probabilities (CCPs) and the property of finite dependence, I tractably estimate a model that includes many alternative choices and uncertainty in choice outcomes.

A key component of my analysis is that search frictions differ based on current employment and residence status. That is, in the style of [Burdett and Mortensen \(1998\)](#), the employed and non-employed face different search processes. This paper builds on their framework by also allowing the search process to differ based on whether a worker has recently moved from another labor market. Descriptive statistics show that these dimensions are important to migration and job search. I show that the non-employed are much more likely than the employed to move.⁴ I also show that employed movers are much less likely to remain in employment than employed stayers. On the other hand, employment probabilities are about the same for non-employed movers and stayers.

Using estimates of worker preferences and productivity, I calculate each type of worker’s willingness to move under alternative scenarios such as a local labor market shock or a government-provided moving subsidy. Migration responses to changes in the local labor market are similar to a spatial labor supply elasticity in the situation where workers have few within-location employment options.⁵

The estimated parameters imply that moving costs are substantial, and that labor market frictions are especially burdensome for the employed. I estimate the moving cost to the average person to have a present value on the order of \$400,000. While large, this estimate is in line with many other studies. The primary reason for the large magnitude is that there is a weak empirical relationship between expected earnings and observed moves. With regard to search frictions, the descriptive finding of reduced job offer arrivals for employed movers continues to hold in the structural model after allowing for employment to depend on unobserved worker ability. Thus, search frictions act as an additional hindrance to migration for the employed. In contrast, the non-employed are equally likely to receive an offer whether or not they move, so search frictions are

²See also [Gould \(2007\)](#); [Kennan and Walker \(2011\)](#); [Baum-Snow and Pavan \(2012\)](#); [Bishop \(2012\)](#); [Coate \(2013\)](#); [Mangum \(2015\)](#); [Bartik \(2018\)](#); [Schluter and Willems \(2018\)](#); and [Schmutz and Sidibé \(2019\)](#) who estimate dynamic models of migration.

³For other papers examining migration as adjustment to labor market shocks, see [Notowidigdo \(2011\)](#); [Sastry and Gregory \(2014\)](#); [Yagan \(2014\)](#); [Gardner and Hendrickson \(2018\)](#); [Huttunen, Møen, and Salvanes \(2018\)](#); [Monras \(2018\)](#); and [Foote, Grosz, and Stevens \(2019\)](#).

⁴See also [Schmutz and Sidibé \(2019\)](#) and [Schlottmann and Herzog \(1981\)](#) who find similar results in other contexts (France and USA, respectively).

⁵This paper abstracts from industry and occupational choice. For a treatment of industry and occupation switching costs, see [Bartik \(2018\)](#). For an examination of oligopsony by occupation, see [Handwerker and Dey \(2019\)](#).

less binding to their migration behavior and their outside options are not affected by moving.

I use the structural model estimates to study migration responses to local labor market shocks, and to a government move subsidy. Employed workers are more likely to *stay* in a place experiencing a local economic downturn, but less so if the economic downturn is nationwide. The opposite is true for the unemployed, who are more likely to move in response to a local economic downturn. If the government were to offer a \$10,000 moving subsidy to the unemployed (e.g. as proposed in the American Worker Mobility Act; [H.R. 2755, 2015](#)), my model predicts that there would be low take-up rates ($\approx 3\% - 5\%$), with even lower take-up rates among those who are already in their home location.⁶ Response to the subsidy differs by the conditions of the local labor market and the desirability of the location.

Taken together, I find that high moving costs, labor market frictions, and preferences for private amenities (such as home location) tend to keep workers in their current location and reduce their outside options. Thus, spatial labor supply elasticity is low ([Balasubramanian et al., Forthcoming](#); [Dube et al., 2018](#); [Hirsch et al., 2018](#)) and firms in sectors with relatively few competitors in the location may be able to compensate their workers below their marginal product of labor. Additionally, these moving costs and search frictions may also reduce the radius of employer recruiting ([Karahan and Rhee, 2017](#); [Krueger and Ashenfelter, 2018](#); [Naidu and Posner, 2018](#); [Webber, Forthcoming](#)).

2 Data and Stylized Facts about Migration and Unemployment

I now introduce the main data sources used in the paper and presents stylized facts about moving costs and labor market frictions that motivate the structural model.

2.1 Data

The main data source is the 2004 and 2008 panels of the Survey of Income and Program Participation (SIPP). I supplement the SIPP with data on location characteristics and local labor market conditions.

2.1.1 The SIPP

The SIPP is a longitudinal survey of a stratified random sample of residents of the United States, administered by the United States Census Bureau. Respondents are interviewed every four months over a four- or five-year span. Each four-month period is referred to as a wave. Survey respondents

⁶See also [Marinescu and Rathelot \(2018\)](#) who find that relocating job seekers to minimize unemployment would have only modest effects on the aggregate unemployment rate. [Caliendo, Künn, and Mahlstedt \(2017\)](#) find that mobility assistance programs in Germany increase geographical mobility of the unemployed.

are asked questions regarding their living arrangements, labor force participation, earnings, assets, government program participation, migration, and education, among many other topics. Within each wave, respondents provide additional information on many of these activities at the monthly level.

In order to preserve confidentiality, the data used here—which make use of detailed residence location and earnings that are not top-coded—are not released publicly by the SIPP and are only available through the Census Research Data Center (RDC) Network.⁷ Furthermore, the confidential version of the SIPP is linked via the respondent’s social security number to Internal Revenue Service (IRS) and Social Security Administration (SSA) administrative data on annual earnings, employment history, government program participation, and social security benefits receipts. I make use of this link to create work experience profiles based on the administrative data that are less vulnerable to survey recall error.

The SIPP’s longitudinal structure, combined with its large-sized cross-section makes it useful for studying migration and labor supply behavior. Because it is a survey, it can distinguish between unemployment and labor force detachment—two effects that are conflated in studies that use administrative data such as tax records (Yagan, 2014; Schluter and Wilemme, 2018; Schmutz and Sidibé, 2019).

The main disadvantages of the SIPP are two-fold. First, its panels are relatively short—four to five years in length. Second, attrition rates in the SIPP are higher than in other longitudinal surveys. However, there is evidence that its high attrition rates do not bias labor market outcomes (Zabel, 1998).

2.1.2 Individual variables

With the data in hand, I now introduce the outcome and explanatory variables used in the analysis. There are three main outcomes of interest: location; labor force and employment status (i.e. employed, unemployed, or out of the labor force); and monthly earnings if employed.

Labor force participation and unemployment are defined in terms of strength of attachment, as follows. Labor force participants are those who have a full-time job or who are seeking a full-time job. Those who are self-employed or who voluntarily work part-time are excluded from my definition of the labor force. Unemployment is defined here as labor force participation that is not full-time employment. Full-time employment is defined as working 35 or more hours per week for all weeks in the survey month.

While the definitions I use for labor force participation and unemployment are unconventional, I use these definitions because my model focuses on the relationship between migration and labor market frictions. People who are only weakly attached to the labor force are by definition less likely

⁷For more information regarding the SIPP, see <http://www.census.gov/sipp/>. For more information about conducting research using confidential data in an RDC, see <https://www.census.gov/fsrdc>.

to move for employment reasons. Later on, I show that my descriptive results are not sensitive to these unconventional definitions of labor force status and employment.

Focusing on full-time employment (rather than any employment) has additional benefits. First, full-time employees are most likely to be employed throughout the year, which more closely matches the time horizon of the model. Second, the SIPP does not measure hours worked at the monthly level—only at the wave level. Thus, measuring earnings at the hourly level is more difficult. I focus on full-time jobs because these jobs are most likely to be salaried, and an hourly earnings measure does not appropriately capture marginal labor productivity for salaried workers.

I define monthly earnings as the sum of earnings across all jobs in the survey month. I deflate earnings by cost of living in the location as described later in this section. All monetary figures throughout this paper are expressed in constant 2000 dollars unless otherwise noted.

The primary explanatory variables are work experience, age, and birth location. I indirectly use additional demographic variables such as education level, sex, and race/ethnicity to determine the estimation subsample. I create work experience from IRS records as an annualized measure of the sum of all quarters worked. I similarly construct age from the SSA data by comparing the calendar year and month with the birth year and month. Respondents report their state or country of birth in Wave 2 of each SIPP panel.

2.1.3 Geographical variables

I define locations as cities (Core Based Statistical Areas or CBSAs).⁸ In order to maintain tractability, I restrict to the 35 cities that are most frequently observed in the SIPP. I construct an additional 20 residual synthetic locations to ensure that the choice set is geographically exhaustive. These synthetic locations are grouped into two population bins (small and medium) based on population. Online Appendix Table A4 contains a complete list of all 55 locations. A map of the 35 cities can be found in Online Appendix Figure A1.

Modeling a large number of locations is essential to capturing the actual locational choice alternatives that individuals face. I focus on cities rather than states because business cycles are heterogeneous across cities, even within the same state.⁹ Furthermore, because many cities cross state boundaries, focusing on cities more closely characterizes the actual local labor market. Modeling the largest cities is also a parsimonious way of categorizing the choice set: 43% of the US population resides in the 30 largest cities (CBSAs).¹⁰ Finally, the residual locations are divided

⁸My definition of city is the Core Based Statistical Area (CBSA) as defined in 2009 by the U.S. Office of Management and Budget (OMB). CBSAs include one or more counties and are defined according to commuting ties. As such, they are a reasonable measure of whether or not a county belongs to a city. Using the 2009 definition, there are a total of 942 CBSAs—366 Metropolitan Statistical Areas (MSAs) and 576 Micropolitan Statistical Areas (μ SAs). Because it is infeasible to estimate a model with this many locations, the choice set is aggregated.

⁹See, e.g., Moretti (2012) who contrasts the labor market trajectories of different areas within California.

¹⁰See https://en.wikipedia.org/wiki/List_of_core-based_statistical_areas.

into population categories because there is evidence in the urban economics literature that a variety of labor market outcomes differ systematically by city size due to agglomeration economies, thick market effects, human capital externalities, and labor market competition (Glaeser and Maré, 2001; Gould, 2007; Baum-Snow and Pavan, 2012; Hirsch et al., 2018). Breaking out the residual categories by city size is a parsimonious way of capturing these effects.

Beyond the geographical definition of location, I also make use of the population, unemployment rate, and price level of the worker’s city. Population is defined as the 2000 Census population level in the county of residence, aggregated to the CBSA level. It is used to divide locations that are smaller than the top 35 cities. The unemployment rate is taken at the county level from the Bureau of Labor Statistics (BLS) Local Area Unemployment Statistics data series and aggregated to the CBSA level, weighting by county population.¹¹ This variable is used in the model to inform individuals about their employment prospects in each location. I merge these city characteristics using a crosswalk that maps counties to CBSAs. Further details on data sources can be found in Online Appendix Table A3.

Following a number of papers in the literature, I spatially deflate earnings using the American Chamber of Commerce Research Association’s Cost of Living Index (ACCRA-COLI).¹² I follow Baum-Snow and Pavan (2012) and Winters (2009). Further details on the construction of this index can be found in Online Appendix Section A.7.

2.1.4 Estimation subsample

I estimate the model using non-Hispanic white men of prime working age (i.e. ages 18–55 at the beginning of the survey) who have completed school and who do not have a bachelor’s degree. I remove college graduates because their job search process across space is much different than that of non-college graduates (Balgova, 2018). I focus on men of a particular education level, race, and ethnicity in order to form a homogeneous sample, and because migration is a household decision where the male head’s employment prospects are more likely to dictate a geographical move.¹³ However, I show later that my basic stylized facts about employment and migration hold for other demographic groups. The final estimation subsample comprises 16,648 men each averaging 3.03 annual observations.

Tables 1 and 2 list descriptive statistics for the estimation subsample. The average individual in the sample is 42 years old and has 23 years of work experience. Living near one’s location of birth is common, with almost 75% of the sample residing in their state of birth. Table 2 lists the migration statistics in the sample, which contains 568 movers who make 653 moves.

¹¹For the 20 residual locations, unemployment is aggregated to the location level.

¹²Studies using this data include: Glaeser and Maré (2001); Kennan and Walker (2011); and Baum-Snow and Pavan (2012), among others.

¹³See Kennan and Walker (2011), Bishop (2012), Bartik (2018) and Wilson (2019, Forthcoming) for other migration studies that focus on a similar demographic group.

I use four annual observations for the 2004 panel—the interview month of waves 2, 5, 8, and 11—to measure location, labor market outcomes, and individual characteristics. The 2008 Panel is slightly longer, so I use the same waves in addition to wave 14. The entire dataset spans the years 2004–2013, but any given individual can only appear in at most five of those years. Most of the sample has at least three observations. For more details on sample selection and construction of key variables, see Online Appendix Section A.6 and Online Appendix Table A1.

2.2 Stylized Facts about Migration and Unemployment

With the data in hand, I now present three stylized facts about migration and unemployment that will show motivating evidence on the two sources of monopsony power that I focus on: moving costs and search frictions.

First, the non-employed are more geographically mobile than the employed. Second, employed workers who move are much less likely to become employed after the move than employed workers who stay. This phenomenon is restricted to employed movers; non-employed movers are just as likely to get a job as non-employed stayers. Third, the employment prospects of non-employed workers are relatively worse during local economic downturns, compared to employed workers. For expositional reasons, I illustrate these facts using publicly available SIPP data on all workers in the United States, as opposed to the confidential data on non-Hispanic white men that I use in the structural model. In all cases, employment is defined as described previously.

Figure 1 shows that, across multiple distances, the non-employed move more frequently than the employed. The difference amounts to about a 50% higher mobility rate for across-state moves, and about a 30% higher mobility rate for within-state, across-county moves.¹⁴

To see if movers and stayers tend to have different employment outcomes, I estimate a simple linear probability model. The left-hand side variable is an indicator for full-time employment in the current period. The right-hand side variables include race-cross-gender dummies, a quadratic in experience, the previous-period unemployment rate in the current state of residence, and an indicator for having made a move since the previous period. Here, I define a move as changing counties or states, i.e. moving to a different local labor market. I estimate this linear probability model separately by previous employment status.

The results of these descriptive regressions are shown in Table 3. For employed workers, the mover dummy coefficient is -12 percentage points, indicating a large penalty for employed movers. For the non-employed, there is actually a slight gain to moving—non-employed movers are about 5 percentage points more likely to be employed than non-employed stayers.¹⁵ Finally, an increase

¹⁴The main result from Figure 1 also holds for a more conventional definition of employment and labor force participation (see Online Appendix Figure A2) as well as for other demographic sub-groups (see Online Appendix Figure A3).

¹⁵These findings can be replicated in other survey data from the US, such as the National Longitudinal Survey of

in the state unemployment rate reduces the employment probability of the non-employed by more than it does the employed. In this sense, the employed are more insulated from local economic downturns than those who are not employed.

While the above facts are illustrative, they are likely biased due to mismeasurement of the local labor market, endogeneity of migration, and unobserved worker heterogeneity. Additionally, the incentives to move faced by the employed and non-employed are myriad and require a more careful unpacking. In the next section, I introduce a structural model in which forward-looking individuals choose where to live and whether to supply labor. Individuals take into account that moving is costly and that employment is uncertain and is affected by local labor market conditions. I then estimate the model on the estimation subsample using restricted-access SIPP data that allows me to more precisely observe local labor markets. The model's inclusion of switching costs and search frictions allows me to examine the extent to which these phenomena might confer monopsony power to firms that have competitors in other labor markets, but not in their own labor market.

3 A Model of Search Frictions, Labor Supply, and Migration

I now introduce the model that I will estimate and use to quantify moving costs, labor market frictions, and to examine counterfactual scenarios that will shed light on workers' spatial responsiveness to changes in their local labor market.

3.1 Overview

In each period, individuals choose whether or not to supply labor in one of 55 locations. The choice set is exhaustive in that it covers every possible location in the United States, and every possible labor market status. Search frictions are a key element of the model. That is, while an individual may control his labor supply decision, he cannot control his employment *outcome*. For example, a non-employed worker may exogenously receive a job offer or an employed worker may exogenously be laid off. Furthermore, these job offer and destruction rates are allowed to vary by location, migration status, and calendar time, thus capturing heterogeneity in local business cycles and spatial frictions in job search. Allowing individuals to choose to supply labor is essential to the model, because the employment probabilities are conditional on labor force participation.¹⁶ I specify the job search parameters in a reduced form, but the underlying search process relates to a [Burdett and Mortensen \(1998\)](#) approach where workers can move locations and enter or exit the labor force.

Youth or the American Community Survey. They also hold for more conventional definitions of labor force participation and employment, as well as for other demographic groups (see Online Appendix Tables [A6](#) and [A7](#)).

¹⁶Additionally, [Amior and Manning \(2018\)](#) argue that local labor supply ratios are key indicators for individuals' economic opportunity.

Individuals are forward-looking and in each period choose the alternative that maximizes their present discounted value of utility. Thus, individuals take into account local labor market conditions when choosing where to locate—in addition to amenities and earnings prospects, which have been traditionally modeled in the migration literature.¹⁷ Individuals also understand that there are costs associated with changing locations or labor force status. These costs motivate individuals to be forward-looking when considering their decision in each period.

This model is the first to examine locational choice and labor supply in a dynamic setting with time-varying search frictions that are tied to local business cycles. It is also the first to examine how moving costs differ by employment status. I now present each feature of the model in more detail, beginning with the individual's dynamic optimization problem. Complete details of the model are included in Online Appendix Section A.1.

3.2 The individual's dynamic optimization problem

In each period t , individual i observes a vector of state variables Z_{it} and preference shocks $\varepsilon_{ij\ell t}$ and receives utility equal to $u_{ij\ell t}(Z_{it}) + \varepsilon_{ij\ell t}$, according to a potential choice pair (j, ℓ) which respectively indexes labor force status and location. The individual sequentially chooses d_{it} to maximize the sum of his present discounted utility according to the following expression:

$$\max_{d_{it}} \mathbb{E} \left[\sum_{t=0}^T \beta^t \sum_j \sum_{\ell} (u_{ij\ell t}(Z_{it}) + \varepsilon_{ij\ell t}) 1\{d_{it} = (j, \ell)\} \right] \quad (3.1)$$

with discount factor β and where $1\{\cdot\}$ is the indicator function. The individual observes the current-period vector of preference shocks ε_{it} before making a decision, but does not observe future shocks and must take expectations accordingly. The individual also may not observe future values of the states Z_{it} and may have to integrate over those as well.

Under mild regularity conditions, (3.2) follows Bellman's optimality principle.¹⁸ The ex ante value function, just before ε_{it} is revealed, is given below.

$$V_{it}(Z_{it}) = \mathbb{E}_{\varepsilon} \max_{j, \ell} \left\{ u_{ij\ell t}(Z_{it}) + \varepsilon_{ij\ell t} + \beta \int V_{it+1}(Z_{it+1}) dF(Z_{it+1}|Z_{it}) \right\} \quad (3.2)$$

Equations (3.1) and (3.2) establish the mathematical framework through which individuals make forward-looking decisions. Specifically, individuals integrate over unknown future prefer-

¹⁷The model relates to Molloy and Wozniak (2011), who examine migration over the business cycle. In my model, individuals are assumed to know what each location's labor market conditions are, as well as their trends and persistence. See also Wilson (2019), who details the role of information on migration decisions.

¹⁸These conditions include additive separability of the flow utility covariates and preference shocks, and conditional independence of the state variables and preference shocks.

ence shock realizations $\varepsilon_{ij\ell t}$ using the value function.¹⁹

3.3 Amenities, expected earnings, employment probabilities, and switching costs

I now briefly discuss how the flow utility terms in (3.2) are specified. The model incorporates unobserved heterogeneity by means of a finite mixture model, where individuals are divided into latent groups. Online Appendix Section A.1 contains complete details of every equation and parameter that enters the model. In all, the model has 1,012 parameters.²⁰

3.3.1 Amenities

Since individuals choose among various locations, amenities are a key component of utility. I specify two types of amenities: local amenities on which all individuals' rankings are identical, and private amenities on which individual rankings may differ. Local amenities include attributes such as climate, crime, and geography. Private amenities include whether the location is in the state or Census division where the individual was born. Specifying private amenities in this way allows for individuals to have preferences for family proximity or other non-market local ties, which have been shown to be an important aspect of location choice (Koşar, Ransom, and van der Klaauw, 2020).

3.3.2 Expected log earnings

Individuals also choose whether or not to supply labor. Naturally, earnings are a function of flow utility if a person becomes employed. However, as a simplifying assumption, I specify that the expected portion of the natural logarithm of earnings is what enters utility.²¹ I assume that expected earnings are composed of a location-time fixed effect, a quadratic function of experience, and a type dummy that represents productivity that is unobserved to the researcher but observed to the individual. Because earnings are a function of a location-time fixed effect, individuals must forecast their future evolution. They do so using an AR(1) process (with drift) specific to each labor market.

¹⁹Individuals are also assumed to know the function F that characterizes the distribution of state transitions. This allows individuals to integrate over future state realizations.

²⁰The earnings model has 544 parameters, the employment probability models have 120 parameters, amenities and moving/switching costs have 72 parameters, and the local labor market forecasting model has 276 parameters.

²¹See Kennan and Walker (2011) and Arcidiacono et al. (2016) who also impose this assumption, although the former study specifies expected earnings in levels rather than logs.

3.3.3 Employment probabilities

Employment probabilities also affect whether someone decides to supply labor. I specify the flow utility of labor force participation to be a weighted sum of the flow utility of being employed (which includes earnings) and the flow utility of being unemployed (which includes a job search cost), where the employment probabilities are the weights.

The employment probabilities follow a form similar to the descriptive linear probability models reported in Table 2: they depend on prior employment status, whether the person is a new move-in, the lagged unemployment rate of the location, and the same unobserved type that enters earnings. As with earnings, individuals must forecast how location-specific employment probabilities will evolve over time. They forecast the local unemployment rate according to an AR(1) process (with drift) specific to each location.

3.3.4 Switching costs

An important component of the flow utility is switching costs. These are specified in two dimensions: switching locations (i.e. moving costs) and switching labor force status. The moving cost includes a constant, a quadratic in distance, a quadratic in age, dummies for prior employment status, and the same unobserved type that enters the earnings and employment probabilities. Labor force switching costs include a constant, a quadratic in age, and the unobserved type.

4 Identification and Estimation

This section informally discusses identification of the model and provides further details on the estimation procedure.

4.1 Identification

I now briefly discuss how the key parameters of the model are identified. These include the earnings and employment parameters, as well as the amenities and moving and switching costs. I provide more comprehensive details on identification in Online Appendix Section A.2.

As with any causal analysis using observational panel data, identification ultimately requires making assumptions. In my case, where the model is a system of non-linear equations, these include the following assumptions: (i) person-specific unobservables follow a discrete distribution; (ii) there are valid exclusion restrictions to tell apart different equations in the model; (iii) individuals pre-commit to working when entering the labor force; and (iv) functional form assumptions that are standard in structural econometrics.²²

²²The standard assumptions include linearity of the model's parameters, additive separability of the error terms,

The unobserved type—which enters the earnings, employment probabilities, and moving and switching costs—is the way in which the model accounts for selection on unobservables. A crucial assumption for identification is that the person-specific unobservables are discretely distributed. Additionally, in a non-linear panel model such as the one used here, the unobservable type needs to be treated as a random effect for consistent estimation. This means that the unobserved type is necessarily uncorrelated with the time-invariant variables included in the model, but it can be correlated with the model’s time-varying variables or other characteristics observed in the data but left out of the model. As with other panel models, identification of this latent type relies on within-person serial correlation in the residuals of each equation. For example, workers with earnings that are persistently higher than their observables would predict are labeled as the “high type.”

Another key to identification is exclusion restrictions for the flow utility. Identification of the coefficient on expected log earnings requires variation in expected log earnings that is not elsewhere present in the flow utility equation. I follow [Arcidiacono et al. \(2016\)](#) in specifying that work experience and calendar time dummies do not enter the flow utility except through expected log earnings. Likewise, the employment probabilities enter the flow utility, and identification of the disutility of unemployment is aided by excluding the local unemployment rate and work experience from the flow utility equation.

Finally, identification of the employment probability parameters also requires the assumption of pre-commitment to work.

4.2 Estimation of earnings, employment, and utility parameters

I estimate the parameters of the model using maximum likelihood and an iterative procedure known as the Expectation-Maximization (EM) algorithm. This is an algorithm that greatly simplifies the estimation of finite mixture models like the one I specify here. The key idea is that I can estimate each equation of the model separately, treating the latent type as given. I fully detail this estimation algorithm in Online Appendix Sections [A.3.1](#) through [A.3.3](#).

Under the simplification of the EM algorithm, estimation of the log earnings equation amounts to weighted OLS. The two employment probability equations—conditional on either employment or non-employment in the previous period—simplify to weighted binary logits. The labor market forecasting equations for the local earnings level and local unemployment rate are each a system of 55 AR(1) equations that are estimated using equation-by-equation OLS.

Estimation of the flow utility parameters is much more involved than the other parameters in the model. This is because the value function in [\(3.2\)](#) is a recursive object and I would need to solve it at each iteration of the maximum likelihood estimation algorithm. Rather than pursue this strategy—which would be computationally infeasible for my model—I break the recursion by

and distributional assumptions on the error terms.

using two separate simplification tools that are closely related: (i) conditional choice probabilities (CCPs; see [Hotz and Miller, 1993](#)); and (ii) finite dependence (see [Arcidiacono and Miller, 2011, 2019](#)). CCPs make use of a function mapping future value terms from the individual’s dynamic programming problem into the probability of making a discrete choice. Finite dependence allows the researcher to formulate the recursive future value terms into a finite sequence of future payoffs. Together, the two strategies yield substantial computational savings by eliminating the need to solve the dynamic programming problem using backwards recursion.

Under the simplification of CCPs and finite dependence, estimation of the recursive flow utility parameters reduces to a multi-stage static problem, which can be estimated using a [McFadden \(1974\)](#) conditional logit model with an adjustment term that captures the future value associated with each alternative.

5 Empirical Results

This section discusses the main estimates of interest. I discuss estimates of employment probabilities, earnings, and unobserved types. I then use the estimates to compute implied moving costs and amenity values. The results show that labor market frictions are especially hindering to employed workers, who see on average a 20 percentage point lower likelihood of finding a job after a move. The results also show that moving costs are large, with an average net present value on the order of -\$400,000. Combined, these two factors inhibit worker flows across labor markets, thus granting market power to firms in sectors where workers have few within-location employment options.

5.1 Employment probabilities, earnings and unobserved types

I begin by discussing the estimated employment probabilities and their evolution over the business cycle, as reported in [Table 4](#). This table lists the estimates of separate binary logits that predict the probability of being employed conditional on previous employment status. I present the estimates for two different specifications: no unobserved heterogeneity, and two unobserved types.²³ The results confirm the findings in [Section 2.2](#): The employed are more shielded from local economic downturns, but employed movers face a steep employment penalty (≈ 20 percentage points) in the new location.²⁴ An additional finding from the structural model is that there is comparative advantage in job-finding based on employment status. That is, type 1 workers are much more likely than type 2 workers to stay employed, but are much less likely to be hired from non-employment.

[Table 5](#) presents estimates of the structural log earnings equation. The main takeaway is that type 1 workers are more productive when employed, as they earn a wage premium of 67 log points

²³For computational reasons, I restrict the number of types to be two.

²⁴The 20 percentage point difference comes from evaluating the logistic function at the estimated parameter values and 0 years of experience, separately for movers and stayers.

over type 2 workers.

As discussed in Section 4.1, unobserved types play a crucial role in accounting for unobservable characteristics and increasing the plausibility of the structural model. By virtue of it being a random effect, the unobserved type is uncorrelated with the the model’s time-invariant state variables. However, it may be correlated with time-varying state variables (such as work experience) or other information in the SIPP that is not included in the model, such as industry, occupation, marital status, home ownership status, or years of completed education.

Without the ability to include measurements of cognitive or non-cognitive skills (since the SIPP does not collect information on these), the interpretation of the unobserved type must come from the equations where it enters in the model. The earnings equation indicates a substantial earnings premium for type 1 workers, and the employment probability equations indicate that type 1 workers are more likely to remain employed. Coupled with the flow utility parameter estimates in Table 6 (which indicate that type 1 workers are more mobile), this suggests that type 1 workers possess higher levels of cognitive and/or non-cognitive skills than type 2 workers.²⁵ The fact that type 1 workers have a comparative advantage in remaining employed could also reflect the variety of industries or occupations they are in. If type 1 workers tend to work in industries or occupations with connections, being employed would open doors to other offers, but it may be difficult to get an offer if unemployed.

5.2 Moving costs and amenity values

Table 6 presents the flow utility parameter estimates, which can be used to compute moving costs and amenity values. The highlight of this table is that both employed and type 1 workers have lower moving costs (i.e. values that are less negative). The former finding is somewhat surprising, given that Figure 1 showed that the employed are less mobile than the non-employed. Combined with the earnings equation estimates, the latter finding is consistent with other studies that have found that cognitive and non-cognitive abilities are correlated with migration—that is, those who are more productive in the labor market also have lower moving costs (Bütikofer and Peri, Forthcoming). In other aspects, the flow utility parameter estimates conform to economic theory and the previous literature.²⁶

²⁵As suggestive evidence on the interpretation of types, I can rule out that the type dummy correlates with marital status. Online Appendix Table A8 reports a modified version of Table 4, where the models include marital status (but not unobserved type) as a regressor. The results imply that unobserved type is only weakly correlated with marital status, because the results in the “Control for marital status” supercolumn are closer to the “1 type” results in Table 4 than they are to the “2 types” results in Table 4. More likely, the type dummy captures persistent unobservables such as cognitive and non-cognitive skills.

²⁶For example, the positive coefficient on expected log earnings indicates that cross-location differences in earnings matter to migration decisions, as found by Kennan and Walker (2011) and others. Individuals value locations that are in their state of birth, more than for locations in their Census division of birth (Diamond, 2016). Fixed costs of moving are substantial, but also steeply increase with distance and age (Bishop, 2012).

Using the parameter estimates in Table 6, I can calculate the monetary value of moving costs and amenity values. The expected earnings parameter can be used to convert utility to money and thus to express the structural parameter estimates in monetary units. I provide complete details in Online Appendix Section A.4 on how this is done. It is also important to note that these moving cost estimates represent the moving costs faced by the *average* individual, not the *marginal* individual (i.e. not the person who is just indifferent between staying and moving). In Table 7, I present sample moving costs by previous employment status and unobserved type in two forms: net present value and percentage equivalent of per-period earnings. The latter form can be used to compare the results with other papers in the dynamic migration literature, while the former can be used to compare the results with other papers that have calculated moving costs in terms of willingness to pay.

In terms of net present value, the fixed cost of moving ranges from -\$105,000 for an employed type 1 person to -\$140,000 for an unemployed type 2 person. The moving cost evaluated at the average person's characteristics and for the average move path ranges from -\$394,000 to -\$459,000. These figures are similar in magnitude to those reported in Kennan and Walker (2011), Bishop (2012), and Bartik (2018).²⁷ Importantly, the monetary value of the moving cost reflects psychological costs of moving (e.g. acclimating to a new location or leaving behind friends and family) in addition to monetary costs (e.g. costs to procure a moving truck or close on a mortgage). In terms of percentage of flow earnings, the fixed cost of moving is between -30% and -40%, meaning that a person would not be willing to move unless he received at least a 30%–40% increase in earnings in perpetuity. For the average move, this number is above 100%. Koşar, Ransom, and van der Klaauw (2020) find similar magnitudes, although their model is static.

In addition to moving costs, I compute amenity values and find them to be economically significant, but not nearly as large as moving costs. The results indicate that a one-standard-deviation increase in local amenities has a net present value of about \$23,000, while moving from the bottom to the top of the amenity distribution would be worth over \$91,000. Preferences for birth state proximity are in between these two values at about \$57,000. This value partly explains why such a high fraction of individuals in the data are observed to be living in their birth state.

One might wonder why the estimated moving costs are so large. The primary reason is that there is a weak relationship between expected earnings and observed moves. Salary is just one of a list of many potential reasons for moving, and while the elasticity of earnings is positive (as predicted by economic theory), the moves observed in the data on average are not strongly related to increases in expected earnings. Additionally, the moving cost represents the cost faced to the average individual if he were forced to move to an arbitrary location in an arbitrary time period,

²⁷Other papers estimating moving costs include Bayer, Keohane, and Timmins (2009); Morten and Oliveira (2016); Diamond (2016) and Shenoy (2016). Exact values of moving costs depend on assumptions of the underlying model, including whether the model is static or dynamic.

and the current model assumes that individuals consider moving to each location in every period.²⁸ This assumption is likely unrealistic, since moving is only salient when certain events in life trigger a move (e.g. pursuit of education, change of job, change of household structure, health of family members, etc.). For recent work that incorporates this feature, see [Schluter and Wilemme \(2018\)](#) and [Schmutz and Sidibé \(2019\)](#). Even if my estimated moving costs are overstated, it is still the case that preferences for non-market amenities and labor market frictions reduce mobility across labor markets.

6 Model Fit and Counterfactual Simulations

In this section, I verify that the structural model fits the data well, and then discuss the results obtained from counterfactual simulations of the model. The results of these simulations illustrate the extent to which workers remain in their labor market in response to a variety of shocks, and hence the extent to which monopsony power operates in sectors with few employers per labor market.

6.1 Model Fit

It is crucial to check the fit of the model to ensure that the model-based counterfactuals are credible. In [Tables 8 and 9](#), I show migration probabilities and employment transitions in the model and in the data. Panel (a) of [Table 8](#) shows how migration varies by previous employment status and calendar time. The model matches these differences well over adjacent time periods. Migration probabilities over previous employment crossed with age and distance are shown in panels (b) and (c) of this table. The model and data also match up well along these dimensions.

[Table 9](#) compares employment transitions across successive time periods in the data and model, conditional on migrating or staying. Panel (a) compares employment transition rates conditional on migrating. These match up very closely with the exception of remaining out of the labor force for non-participants. This is likely due to the fact that, in the data, there are relatively few non-participant movers who remained out of the labor force after moving. Panel (b) compares these transitions conditional on staying in a location. Again, the data and model match up well.

I present the model fit for adjacent time periods—and not longer horizons—because the counterfactual simulations also only cover adjacent time periods. The reason for only considering counterfactuals of this sort stems from how the model is estimated. The CCP method explained in [Section 4.2](#) eliminates the need to solve the value function. It also allows the future value terms to not be driven by assumptions about how expectations are formed far out into the future. The

²⁸Allowing the individual to choose the best available location would substantially reduce this cost. [Kennan and Walker \(2011\)](#) also show that the moving cost for actual moves is much lower than for the average mover. A similar line of logic applies to the current model, but I omit the discussion here for expositional purposes.

downside is that these future value terms are not valid in counterfactual scenarios that go beyond $t + 1$. Counterfactuals covering a longer time period would require fully solving the value function, which in this case is computationally infeasible.

6.2 Counterfactual Simulations

Now that I have established that the model fits the data well, I discuss counterfactual simulations of the model that further illustrate the importance of moving costs and search frictions. To get a sense of the degree to which workers would migrate, I simulate the migration response to five different counterfactual policies of 25-year-olds who were not born in the location. I examine heterogeneity in migratory response by separately analyzing each unobserved worker type living in two artificial cities—one with very desirable amenities, and the other with very undesirable amenities.²⁹

The five policies I examine are the following: two separate shocks to local expected earnings; two separate shocks to the local unemployment rate; and a moving subsidy worth 10% of the fixed cost of moving (\approx \$10,000 in net present value). For earnings and unemployment, I respectively consider a purely localized shock and a shock that is spatially correlated (but originating in the current location).³⁰ For reasons discussed above, I only examine temporary counterfactual policies. That is, each policy is in effect for only one calendar year. However, because of the autocorrelated structure of some components of the model, the *effect* of each counterfactual policy may not be temporary.

I focus my discussion on the impact of the policies on out-migration of young workers who were not born in the impacted location, because these are the workers who are most responsive to such policies. As such, the migration responses I document are upper bounds on the population-level average response: repeating the exercise for older workers, or for workers born in the origin location would result in much lower responses because these other groups are more tied to their current location.

The results of the simulations are reported in Figure 2, which show the change in out-migration probability for each policy. Baseline predicted out-migration rates for each city and employment

²⁹Additional results for four other artificial cities and for unemployment and labor supply responses are included in the Online Appendix. The six locations correspond to three pairs of artificial cities, each possessing characteristics at specific points in the respective distribution of city characteristics for local amenities, earnings, and employment probabilities. For example, I calculate the difference in the probability of out-migration with and without the policy in a city at the 75th percentile of the amenities distribution versus a city at the 25th percentile of the amenities distribution. All other city characteristics are identical across the two cities. In all cases, the artificial city is set to be in the same geographical location. The exact geographical location of the artificial city makes little difference to the final results. This process is repeated for earnings and employment probabilities. Constructing the counterfactuals in this way allows me to hold fixed city characteristics, which turn out to be important determinants of migration behavior (Coate and Mangum, 2019).

³⁰The degree of spatial correlation is that implied by the correlation of the residuals in the system of autocorrelation equations.

group are listed just above the horizontal axis.³¹ The first four bars in each panel report the simulated response to independent and correlated adverse shocks to earnings and employment in each location, while the last bar reports the moving subsidy response.³²

The key result from Figure 2 is the difference in behavior between employed and unemployed workers when faced with unemployment shocks (the third and fourth bars).³³ This difference stems from the difference in employment probabilities that these groups face when moving, and highlights the importance of labor market frictions in explaining worker mobility across labor markets. Employed workers are more likely to stay in their current location when faced with either a localized or correlated shock, whereas the opposite is true for unemployed workers.³⁴

In addition to the importance of labor market frictions, Figure 2 also shows the role of moving costs in explaining migration behavior. The last bar of each panel of Figure 2 reports the simulated impact of a moving cost subsidy of approximately \$10,000 (10% of the fixed cost of moving for employed type 1 workers). For all cities and employment statuses, out-migration rates increase, but are relatively modest. The increase in migration probability is on the order of 33% (or an increase of no more than 5 percentage points off a base of 15%).³⁵

The results of these counterfactual simulations illustrate the importance of labor market frictions and moving costs in inhibiting the movement of workers across labor markets, even if workers are offered a sizable moving subsidy. These findings together imply that workers' outside options are limited by inability or unwillingness to move, which leads to monopsony power (Manning, 2003). Since the model does not account for within-location job switching, these results are most informative for workers in industries with few within-location employer options. High moving

³¹These migration rates are heterogeneous across cities, employment status, and type. In particular, predicted out-migration is highest for the city with the lowest amenities, and for those who are type 1. In contrast, out-migration is smallest for the city with high amenities and those who are type 2. These results point to the importance of considering amenities when forming policy that is intended to affect migration behavior. The baseline migration rates also differ markedly by employment status. The rate of out-migration for unemployed workers is 1.2 to 1.5 times the rate for employed workers, consistent with the stylized facts presented in Figure 1. However, there is substantial heterogeneity across cities and unobserved worker types.

³²The earnings shock corresponds to the 70th percentile of the cross-location distribution in earnings AR(1) shock deviations. The unemployment shock corresponds to the 2008–2009 increase in the local unemployment rate for the average location in the data.

³³These findings contrast with those of Gardner and Hendrickson (2018), who show that labor markets with higher variance in unemployment rates have lower out-migration rates, all else equal. My approach underscores that moving incentives differ drastically by employment status.

³⁴There is also substantial heterogeneity in migration responses to local economic shocks with respect to unobserved type. For example, employed type 1 workers are more likely than type 2 workers to stay in response to each of the four shocks. This is because type 2 workers have a comparative advantage in job finding, and employed movers are much less likely to find a job upon arrival in a new location. The comparative advantage of type 2 workers also explains why unemployed type 2 workers are more likely than unemployed type 1 workers to leave in response to an unemployment shock. This is true even though type 2 individuals have larger moving costs.

³⁵There is also heterogeneity in the moving subsidy response. The increase is largest in areas with low amenities. Unemployed workers are more responsive to each subsidy, even though they have larger moving costs. The reason ties back to the fact that unemployed movers do not face an employment penalty. Finally, type 2 workers are more likely to stay because their moving costs are higher.

costs may also induce firms to reduce their geographical recruitment radius, as discussed in [Karan and Rhee \(2017\)](#).

7 Conclusion

Search frictions and switching costs are thought to grant monopsony power to incumbent employers because they reduce workers' outside options. This paper has studied the extent to which labor market frictions and moving costs inhibit migration of American workers who are not college graduates. To quantify these two determinants of employer market power, I have developed and tractably estimated a rich dynamic structural model that incorporates search frictions.

I find that moving costs are substantial and that employed movers see a steep reduction in the job-finding rate after a move. Moving costs are large because migration decisions observed in the data are only loosely related to cross-location earnings differences. That is, workers have sizable preferences for market and non-market amenities which weaken the role of earnings in the migration decision. Labor market frictions are also important. Even though the employed have lower moving costs, counterfactual simulations of the model show that they are *less* likely to move in response to a shock to the local unemployment rate. This is because they face a steep decline in employment likelihood if they move locations.

I use the model to simulate the effect of a moving subsidy offered to both employed and unemployed workers. Owing to large moving costs, the subsidy has low take-up rates ($\approx 3\% - 5\%$). The unemployed are more likely to take the subsidy, because they have roughly the same likelihood of employment whether or not they move.

Because this paper does not model within-location job switching, its results are most applicable to industries where there are relatively few within-location employment options. Examples of such industries include resource extraction, television or radio journalism, and those who work at airports or other ports of entry. Current work by [Bartik \(2018\)](#) examines how workers respond to labor market shocks by trading off switching locations, switching industries and switching occupations.

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Figures and Tables

Table 1: Descriptive statistics of the estimation subsample of the SIPP, 2004-2013

Variable	Mean	Std Dev
Log monthly earnings (2000 dollars) ^a	7.96	0.52
Work experience (years)	22.60	9.49
Age (years)	42.29	9.76
Lives in location in birth state	0.74	0.44
Lives in location in birth Census division	0.75	0.43
Number of persons	16,648	
Number of observations	50,415	

Notes: For complete sample selection rules, see Online Appendix Table [A1](#).

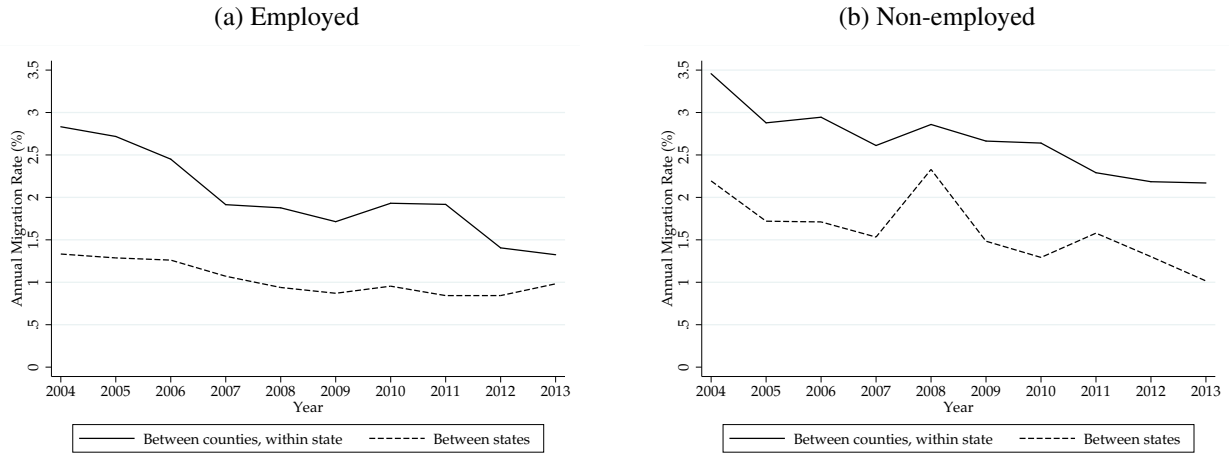
^a Conditional on being employed full-time with monthly earnings between \$400 and \$22,000. This variable has 29,238 person-year observations. The earnings variable is spatially deflated to account for differences in cost of living according to the procedure outlined in Appendix [A.7](#)

Table 2: Migration in the SIPP, 2004-2013

Number of persons (age 18-55)	16,648
Movers	568
Movers (%)	3.41
Moves	653
Moves per mover	1.15
Repeat moves (% of all moves)	13.38
Return moves (% of all moves)	8.98

Note: Moves are defined as changing locations as defined in the model.

Figure 1: Annual migration rates by lagged employment status and migration distance



Source: 2004 and 2008 Panels of the Survey of Income and Program Participation. Figures include all non-college graduates aged 18-55 who have completed their schooling. Employment is defined as full-time employment.

Table 3: Linear probability models of employment, by lagged employment status

Variable	Prev. employed		Prev. non-employed	
	Coeff	Std Err	Coeff	Std Err
Constant	0.7243***	0.0071	0.1976***	0.0059
Experience	0.0123***	0.0005	0.0077***	0.0004
Experience ² /100	-0.0200***	0.0012	-0.0142***	0.0011
Lagged state unempl. rate	-0.0038***	0.0006	-0.0060***	0.0006
Mover dummy	-0.1219***	0.0080	0.0468***	0.0076
Race \times gender dummies	✓		✓	
Observations	83,324		78,057	

Notes: Dependent variable is an indicator for being employed full-time in the current period. Sample includes all non-college graduates aged 18-55 in the 2004 and 2008 panels of the public-use SIPP who have completed their schooling. *** p<0.01; ** p<0.05; * p<0.10.

Table 4: Structural employment probability equation estimates

Variable	1 type				2 types			
	Prev. employed		Prev. non-employed		Prev. employed		Prev. non-employed	
	Coeff	Std Err	Coeff	Std Err	Coeff	Std Err	Coeff	Std Err
Constant	1.3056***	0.2220	0.2566	0.2237	0.9812***	0.2241	0.5035***	0.2264
Experience	0.0858***	0.0091	0.0359***	0.0086	0.0847***	0.0092	0.0366***	0.0087
Experience ² /100	-0.1228***	0.0208	-0.0285	0.0219	-0.1224***	0.0211	-0.0310	0.0221
Lagged local unempl. rate	-0.0314***	0.0104	-0.0922***	0.0110	-0.0342***	0.0105	-0.0937***	0.0111
Mover dummy	-0.9257***	0.1280	0.1929	0.1557	-1.0483***	0.1300	0.2359	0.1572
Unobserved type 1					0.7958***	0.0400	-0.5751***	0.0429
Location fixed effects	✓		✓		✓		✓	
Observations	30,898		9,949		30,898		9,949	
Persons	12,013		6,087		12,013		6,087	

Notes: Reported numbers are coefficients from logit regressions conditional on previous employment status. *** p<0.01; ** p<0.05; * p<0.10.

Table 5: Structural earnings equation estimates

Parameter	1 type		2 types	
	Coeff	Std Err	Coeff	Std Err
Constant	7.5708***	0.0673	7.2074***	0.0470
Experience	0.0432***	0.0015	0.0411***	0.0010
Experience ² /100	-0.0595***	0.0033	-0.0575***	0.0023
Unobserved type 1			0.6773***	0.0039
Location-time fixed effects	✓		✓	
Persons	11,404		11,404	
Observations	29,238		29,238	

Notes: Reported numbers are coefficients from an OLS log earnings regression conditional on full-time employment and observing earnings. See footnote (a) of Table 1 for complete details on this subsample. *** p<0.01; ** p<0.05; * p<0.10

Table 6: Structural choice equation estimates

Parameter	Symbol	1 type		2 types	
		Coeff	Std Err	Coeff	Std Err
<i>Job & location preferences</i>					
Expected log earnings	(γ_0)	0.916**	0.397	1.001**	0.412
Home production benefit	(γ_1)	-0.902	3.477	11.333***	3.453
Search cost	(γ_2)	-1.195***	0.069	-1.008***	0.070
Birth state bonus	(γ_3)	0.207***	0.072	0.210***	0.072
Birth division bonus	(γ_4)	-0.002	0.073	-0.003	0.073
<i>Switching costs</i>					
Fixed cost	($\theta_{12} - \theta_8$)	0.335**	0.127	0.910***	0.126
Age	($\theta_{13} - \theta_9$)	-0.095***	0.006	-0.106***	0.006
Age ² /100	($\theta_{14} - \theta_{10}$)	0.109***	0.008	0.121***	0.008
Unobserved type 1	($\theta_{15} - \theta_{11}$)			-0.746***	0.019
<i>Moving costs</i>					
Fixed cost	(θ_0)	-3.148***	0.361	-3.165***	0.362
Distance (1000 miles)	(θ_1)	-2.063***	0.078	-2.066***	0.078
Distance ²	(θ_2)	0.369***	0.025	0.369***	0.025
Age	(θ_3)	-0.094***	0.018	-0.101***	0.018
Age ² /100	(θ_4)	0.056**	0.023	0.063***	0.023
Employed _{<i>t</i>-1}	(θ_5)	0.197*	0.110	0.252**	0.110
Unemployed _{<i>t</i>-1}	(θ_6)	-0.230*	0.128	-0.239*	0.129
Unobserved type 1	(θ_7)			0.256***	0.045
Pr(type = 1)	($\bar{\pi}_r$)	N/A		0.4926	
Observations		50,415		50,415	
Persons		16,648		16,648	
Discount factor	(β)	0.9		0.9	

Notes: Reported numbers are flow utility parameter estimates from the dynamic choice model detailed in Online Appendix Section A.1. Estimates of location-specific amenities (the α_ℓ 's) are not reported due to Census Bureau rules regarding disclosure risk. *** p<0.01; ** p<0.05; * p<0.10

Table 7: Sample moving costs and amenity values in net present value and percentage of flow earnings)

Utility component	Monetary value			
	Type 1		Type 2	
	Employed	Unemployed	Employed	Unemployed
<i>Panel A: Net Present Value (\$)</i>				
<i>Moving costs</i>				
Fixed cost of moving	-105,095	-127,749	-116,777	-140,023
Average mover, 500-mile move	-394,446	-436,458	-416,095	-459,270
Average mover, NY to LA	-570,671	-622,158	-597,202	-650,115
Young mover, NY to LA	-312,595	-342,163	-327,841	-358,186
<i>Amenities</i>				
Std. Dev. of local amenities		23,356		
Range of local amenities		91,603		
Birth state bonus		57,328		
<i>Panel B: Percentage of Flow Earnings</i>				
<i>Moving costs</i>				
Fixed cost of moving	-30.6	-37.3	-34.1	-40.8
Average mover, 500-mile move	-101.9	-112.8	-107.5	-118.7
Average mover, NY to LA	-147.5	-160.8	-154.4	-168.0
Young mover, NY to LA	-116.9	-128.0	-122.6	-134.0
<i>Amenities</i>				
Std. Dev. of local amenities		7.7		
Range of local amenities		30.2		
Birth state bonus		18.9		

Notes: Panel A expresses the monetary values in terms of net present value, while Panel B expresses monetary values in terms of the percentage of flow earnings. All results are derived from the parameter estimates in Table 6. The average mover is age 39, and a young mover is age 25. The great-circle distance from New York to Los Angeles is 2,446 miles. For complete details on how these values are calculated, see Online Appendix Section A.4.

Table 8: Model fit: observed vs. predicted migration probabilities

(a) Migration probabilities by calendar time and $t - 1$ employment status

$t - 1$ Employment status	2004-2008		2009-2013		All	
	Data	Model	Data	Model	Data	Model
Employed	1.30%	1.33%	1.28%	1.24%	1.29%	1.29%
Unemployed	1.21%	1.25%	1.15%	1.10%	1.19%	1.19%
Out of labor force	1.88%	1.73%	1.52%	1.66%	1.69%	1.70%
Overall	1.14%	1.27%	1.38%	1.22%	1.25%	1.25%

(b) Migration probabilities by age and $t - 1$ employment status

Age range	Employed		Unemployed		Out of LF		All	
	Data	Model	Data	Model	Data	Model	Data	Model
18-25	2.31%	2.11%	2.54%	3.62%	3.37%	3.31%	2.52%	2.84%
26-35	1.90%	1.65%	2.31%	2.32%	1.97%	2.13%	2.00%	1.86%
36-45	1.00%	1.20%	1.57%	1.42%	1.23%	1.30%	1.13%	1.25%
46-55	0.80%	0.82%	1.09%	0.85%	0.88%	0.84%	0.86%	0.83%

(c) Migration probabilities by distance migrated and $t - 1$ employment status

Distance (miles)	Employed		Unemployed		Out of LF		All	
	Data	Model	Data	Model	Data	Model	Data	Model
0-500	0.72%	0.70%	0.68%	0.65%	0.92%	0.94%	0.72%	0.70%
501-1,000	0.31%	0.35%	0.29%	0.33%	0.41%	0.45%	0.31%	0.35%
1,001-1,500	0.13%	0.13%	0.10%	0.12%	0.20%	0.17%	0.13%	0.13%
1,501-2,000	0.07%	0.05%	0.06%	0.05%	0.11%	0.07%	0.07%	0.05%
2,001+	0.06%	0.05%	0.07%	0.04%	0.05%	0.06%	0.06%	0.05%

Notes: All numbers in this table correspond to migration probabilities (multiplied by 100 and expressed as percentages). Data probabilities consist of conditional means of an indicator for migration. Model probabilities consist of conditional means of the predicted probability of leaving the current location.

Table 9: Model fit: employment transitions by migration status

(a) Employment transitions conditional on migrating

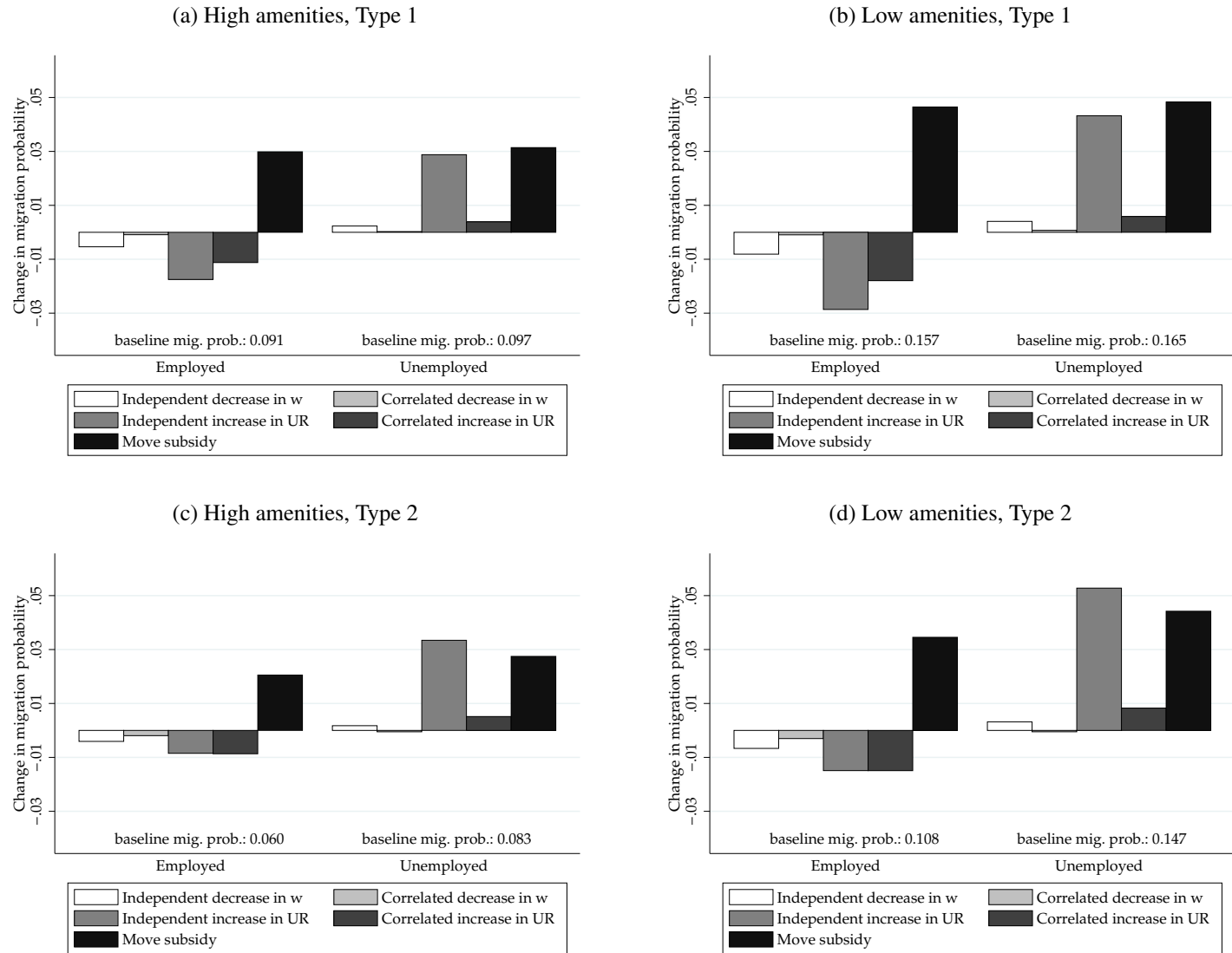
Period t						
Period $t - 1$	Data			Model		
	E	U	N	E	U	N
Employed (E)	70.98%	22.69%	6.33%	71.99%	22.26%	5.75%
Unemployed (U)	41.40%	46.50%	12.10%	45.06%	44.77%	10.17%
Out of labor force (N)	16.52%	17.39%	66.09%	13.88%	12.58%	73.54%

(b) Employment transitions conditional on staying

Period t						
Period $t - 1$	Data			Model		
	E	U	N	E	U	N
Employed (E)	86.92%	9.86%	3.23%	86.45%	9.83%	3.71%
Unemployed (U)	36.33%	49.75%	13.93%	38.09%	49.60%	12.31%
Out of labor force (N)	10.81%	10.41%	78.78%	10.56%	12.22%	77.21%

Notes: All numbers in this table correspond to employment transition probabilities (multiplied by 100 and expressed as percentages). Data probabilities consist of conditional means of employment transition by migration status. Model probabilities consist of conditional means (by employment status) of the predicted conditional probability of making an employment transition (conditional on leaving or staying).

Figure 2: Counterfactual changes in migration by origin city, prior employment status, and unobserved worker type



Notes: Each panel corresponds to a different origin city and unobserved type. Bar heights refer to the change in the out-migration rate from the specified location in response to the listed counterfactual. All figures are for 25-year-olds who were not born in the origin location. “high” refers to a location in the 75th percentile of the given distribution; “low” refers to the 25th percentile. All characteristics not set to “high” or “low” are set to the median. The earnings shock ($\downarrow w$) corresponds to the 70th percentile of the cross-location distribution in earnings AR(1) shock deviations. The unemployment shock corresponds to the jump from 2008 to 2009 for the average location in the data. To focus the results, each candidate location has median AR(1) parameters for both earnings and employment. Birth location is held fixed in all counterfactuals. Individual characteristics are set to the average for all 25-year-olds, conditional on employment status.

A Online Appendix

This appendix is organized as follows. Section A.1 provides complete details of each component of the structural model. Section A.2 discusses identification in further detail, and Section A.3 provides complete detail on how I estimate the model. Section A.4 explains how I calculate moving costs and amenity values, and Section A.5 evaluates destination location choice in the counterfactual simulation. Section A.6 explains details on selecting the estimation subsample, while Section A.7 explains how I account for cost of living. Section A.8 explains the sampling design of the SIPP. All appendix tables are included after Section A.8.

A.1 Detailed definition of the structural model

This section of the Online Appendix presents each element of the model in complete detail.³⁶

A.1.1 Earnings

Monthly earnings for individual i in location ℓ of unobserved type r and calendar year t are a function of location-year fixed effects $\psi_{0\ell t}$, work experience x_{it} , a person-specific unobserved type indicator τ_{ir} , and measurement error $\eta_{i\ell t}$. The log earnings equation is

$$\ln w_{i\ell t} = \psi_{0\ell t} + \psi_1 G(x_{it}) + \psi_2 \tau_{ir} + \eta_{i\ell t} \quad (\text{A.1})$$

where $G(\cdot)$ is a quadratic polynomial. Human capital accumulation is accounted for by including work experience as a determinant of earnings. Person-specific unobserved heterogeneity in earnings is captured by the discrete type indicator τ_{ir} . Cross-location heterogeneity and nonstationarity in earnings is accounted for by the location-year fixed effects, which allow for business cycle effects to be different across locations. Importantly, individuals observe the time dummies in calendar year t but must form expectations about their evolution in future periods. Measurement error $\eta_{i\ell t}$ is assumed to be distributed $N(0, \sigma_\eta^2)$ and independent over time, locations, and all other state variables.

³⁶A cross-referenced notation glossary for all Greek symbols is available in Online Appendix Table A13.

Forecasting earnings Individuals are uncertain about future realizations of the $\psi_{0\ell t}$'s and the $\eta_{i\ell t}$'s. They forecast future earnings according to an AR(1) process (with drift) on the location-year fixed effects $\psi_{0\ell t}$:

$$\psi_{0\ell t} = \rho_{0\ell} + \rho_1 \psi_{0\ell t-1} + \zeta_{\ell t} \quad (\text{A.2})$$

where $\zeta_{\ell t}$ is distributed $N(0, \sigma_{\zeta_{\ell}}^2)$. In other words, individuals know the drift and autocorrelation coefficients ($\rho_{0\ell}$ and ρ_1) and shock variances ($\sigma_{\zeta_{\ell}}^2$) for each location, and integrate over future realizations of $\zeta_{\ell t}$ using information about the distribution from which $\zeta_{\ell t}$ is drawn.³⁷

Individuals also forecast future earnings innovations $\eta_{i\ell t}$ but do not need to integrate over any distribution because the $\eta_{i\ell t}$'s are measurement error and assumed to be mean-zero and independent over time, and because they are assumed to not affect decisions.

A.1.2 Employment probabilities

Individuals who choose to supply labor obtain employment with probability $\pi_{i\ell rt}$, which depends on their level of work experience x_{it} , their unobserved type τ_i , their current location ℓ , their previous location and employment status, and the previous unemployment rate in each location.

$$\pi_{i\ell rt}(x_{it}, \tau_i, UR_{\ell t-1}) = \begin{cases} (1 - \delta_{i\ell rt}) & \text{if employed in } \ell \text{ in } t-1 \\ \lambda_{i\ell rt} & \text{if not employed in } \ell \text{ in } t-1 \\ \lambda_{i\ell rt}^e & \text{if employed in } \ell' \neq \ell \text{ in } t-1 \\ \lambda_{i\ell rt}^u & \text{if not employed in } \ell' \neq \ell \text{ in } t-1 \end{cases} \quad (\text{A.3})$$

Equation (A.3) operates as follows. Individuals arrive in a location and, if choosing to supply labor, are entered into a lottery that assigns them employment with probability $\pi_{i\ell rt}$. Individuals pre-commit to working if they are assigned to employment.³⁸ Employed individuals are thus laid off with probability $\delta_{i\ell rt}$ and unemployed individuals receive a job offer with probability $\lambda_{i\ell rt}$.

³⁷The assumption that ρ_1 is not location-specific has also been made by [Kaplan and Schulhofer-Wohl \(2017\)](#).

³⁸In this sense, individuals choose locations not by the availability of job offers, but by the likelihood of finding a job once in the destination location. Thus, workers search for a job in the location upon arrival. This motivates the sample selection discussed previously, since this group of people is more likely to move before finding a job ([Balgova, 2018](#)).

Individuals coming from employment in another location receive an offer with probability $\lambda_{i\ell r t}^e$. Individuals coming from non-employment in another location receive an offer with probability $\lambda_{i\ell r t}^u$. In particular, these employment probability parameters are indexed by location and time, which allows for heterogeneous business cycles across locations—a trend seen in the data. As with other non-stationary parameters in the model, individuals observe these probabilities in calendar year t but must form expectations about their evolution in future periods.

The model introduces search frictions in a reduced form primarily for computational reasons. Adding non-market migration and labor force participation to an equilibrium search model would be computationally prohibitive.³⁹

In practice, each of the employment probabilities is parameterized as a predicted logistic probability, where the logistic regression has right hand side variables as follows: location fixed effects, lagged unemployment rate, an unobserved type indicator, and a mover dummy. Non-stationarity enters the employment probabilities through movements in the lagged unemployment rate, which I now detail.

Forecasting employment probabilities Individuals forecast future employment probabilities according to an AR(1) process (with drift) on the local unemployment rate $UR_{\ell t}$:

$$UR_{\ell t} = \phi_{0\ell} + \phi_{1\ell} UR_{\ell t-1} + \xi_{\ell t} \quad (\text{A.4})$$

where, again, individuals know the shock variance and autocorrelation of the $UR_{\ell t-1}$'s in each location, but integrate over possible realizations of the $\xi_{\ell t}$'s given realizations of $UR_{\ell t-1}$. $\xi_{\ell t}$ is assumed to be drawn from a distribution that is $N(0, \sigma_{\xi_{\ell}}^2)$.

This implies that, for each t , the time- t forecast of the future employment probability is

$$\mathbb{E}_t \pi_{i\ell t+1} = \int_{\xi_{\ell}} \Pr\{\mu_2(\phi_{0\ell} + \phi_{1\ell} UR_{\ell t} + \xi_{\ell t+1}) + z_{i\ell r} \mu > 0\} dF(\xi_{\ell t+1}) \quad (\text{A.5})$$

where the argument inside the probability is a latent linear index comprised of μ_2 , a parameter

³⁹For a treatment of migration in the style of a classical job search model, see [Schluter and Willems \(2018\)](#) and [Schmutz and Sidibé \(2019\)](#). For recent work on extending classical job search models to include preference heterogeneity over non-wage amenities, see [Sullivan and To \(2014\)](#); [Taber and Vejin \(2020\)](#); [Hall and Mueller \(2018\)](#); [Sorkin \(2018\)](#).

governing the relationship between the lagged unemployment rate in location ℓ and the employment probability, and $z_{i\ell r}\mu$, which represents other right-hand side variables and parameters in the probability that are stationary (e.g. location, work experience, unobserved type). In practice, μ_2 is allowed to vary by employment status to capture the fact that unemployed workers are more vulnerable to economic downturns. More details on the form and estimation of these probabilities are given in section 4.2.

A.1.3 State variables, flow utilities, and stochastic employment

Denote by $d_{it} = (j, \ell)$ the choice for individual i in calendar year t , where $j \in \{0, 1\}$ indexes labor force status, $\ell \in \{1, \dots, L\}$ indexes locations, and $\mathcal{J} = \{0, 1\} \times \{1, \dots, L\}$ denotes the entire choice set. Labor force participation is denoted by $j = 1$ while $j = 0$ indicates out of the labor force. As mentioned before, individuals control their labor supply decision, but not their employment outcome. To differentiate between the two, let $y_{it} \in \{e, u, n\} \times \{1, \dots, L\}$ be the choice *outcome*, where e denotes employment, u unemployment, and n non-participation. The set $\{1, \dots, L\}$ covers all possible locations in the United States. A complete list of these locations can be found in Online Appendix Table A4.

Let Z_{it} denote the state variables for individual i in calendar year t . Z_{it} contains work experience, age, calendar time t , previous decision d_{it-1} , previous employment outcome y_{it-1} , and unobserved type τ_i . The flow utility associated with making choice (j, ℓ) is a function of the observed state variables and unobservables $\varepsilon_{ij\ell t}$:

$$U_{ij\ell t}(Z_{it}, \varepsilon_{ij\ell t}) = u_{ij\ell t}(Z_{it}) + \varepsilon_{ij\ell t} \quad (\text{A.6})$$

The flow payoffs associated with choices j and ℓ are an expectation of the employment outcomes because individuals pre-commit to working if they get a job offer:

$$u_{i1\ell t}(Z_{it}) = \pi_{i\ell rt}(Z_{it}) u_{i\ell t}^e(Z_{it}) + (1 - \pi_{i\ell rt}(Z_{it})) u_{i\ell t}^u(Z_{it}) \quad (\text{A.7})$$

$$u_{i0\ell t}(Z_{it}) = u_{i\ell t}^n(Z_{it}) \quad (\text{A.8})$$

The flow utility corresponding to each employment outcome is given by

$$u_{i\ell t}^e(Z_{it}) = \alpha_\ell + \Delta_\ell(Z_{it}) + \Xi_1(Z_{it}) + \gamma_3 b_{i\ell}^{ST} + \gamma_4 b_{i\ell}^{DIV} + \gamma_0 \ln \tilde{w}_{i\ell t}(Z_{it}) \quad (\text{A.9})$$

$$u_{i\ell t}^u(Z_{it}) = \alpha_\ell + \Delta_\ell(Z_{it}) + \Xi_1(Z_{it}) + \gamma_3 b_{i\ell}^{ST} + \gamma_4 b_{i\ell}^{DIV} + \gamma_1 + \gamma_2 \quad (\text{A.10})$$

$$u_{i\ell t}^n(Z_{it}) = \alpha_\ell + \Delta_\ell(Z_{it}) + \Xi_0(Z_{it}) + \gamma_3 b_{i\ell}^{ST} + \gamma_4 b_{i\ell}^{DIV} + \gamma_1 \quad (\text{A.11})$$

The first term α_ℓ is a location fixed effect measuring the net value of all amenities in location ℓ . The variables $b_{i\ell}^{ST}$ and $b_{i\ell}^{DIV}$ are dummies that indicate if the individual was born in any of the states (*ST*) or Census divisions (*DIV*) contained in location ℓ .⁴⁰ $\ln \tilde{w}_{i\ell t}(Z_{it})$ is the deterministic component of log earnings for an individual in location ℓ with states Z_{it} , γ_1 is a home production benefit, and γ_2 is a net cost of searching for employment.⁴¹ Home production benefits and search costs are constant across locations. $\Delta_\ell(Z_{it})$ are costs of moving to ℓ which are incurred if the previous location is different from ℓ . Likewise, $\Xi(Z_{it})$ are labor supply switching costs which are incurred whenever a person enters or exits the labor force. The unobserved part of the flow utility $\varepsilon_{ij\ell t}$ is a preference shock, but can equivalently be thought of as a shock to moving costs or switching costs. These preference shocks are assumed to be drawn from a standard Type I extreme value distribution, independently across i , j , ℓ , and t . The $\varepsilon_{ij\ell t}$'s are also independent of the other variables in the model.

A.1.4 Moving costs and switching costs

Moving costs Let h indicate the previous location, which is embedded in Z_{it} , and define $D(\ell, h)$ as the great circle distance between the two locations. The moving costs are a function of a fixed cost, distance, age, previous employment status, and unobserved type, and are specified as

$$\begin{aligned} \Delta_\ell(Z_{it}) = & (\theta_0 + \theta_1 D(\ell, h) + \theta_2 D^2(\ell, h) + \theta_3 \text{age}_{it} + \theta_4 \text{age}_{it}^2 + \\ & \theta_5 \text{employed}_{it-1} + \theta_6 \text{unemployed}_{it-1} + \theta_7 \tau_i) 1\{\ell \neq h\} \end{aligned} \quad (\text{A.12})$$

⁴⁰For example, an individual born in Indiana would have this dummy turned on for the following locations: Indianapolis, Chicago, and the two East North Central Census division synthetic locations. There are two cities in the model that straddle Census divisions: New York City and St. Louis, MO.

⁴¹While γ_1 is labeled as a benefit and γ_2 a cost, the sign of each is freely estimated. γ_2 can be thought of as the additional cost to searching off-the-job relative to on-the-job.

where $1\{A\}$ is an indicator meaning that A is true. Moving costs are specified in a reduced-form manner to flexibly capture trends in the data. This specification is in line with [Kennan and Walker \(2011\)](#) and [Bishop \(2012\)](#).⁴² Additionally, I allow the moving cost to differ by previous employment status to capture the possibility that the non-employed are financially constrained, or the employed are more tied to a location. This dimension of moving costs has not been explored previously in the literature.

The intercept θ_0 corresponds to the fixed cost of moving, while θ_1 and θ_2 capture the fact that moving costs increase with distance, but at a potentially decreasing rate. θ_3 and θ_4 capture a similar idea with age. θ_5 and θ_6 are included to capture differences in psychic costs and financial costs for those who were previously employed compared with those who were previously unemployed.⁴³ θ_7 captures the fact that some moving costs may be unobserved to the researcher. The signs on the θ 's are written here as being positive but are allowed to be freely estimated. The fixed cost and linear terms of distance and age are expected to have a negative sign, while the signs on the two quadratic terms are expected to be positive. The expected sign of the previous employment status dummies is ambiguous because, for example, while employed individuals might have more financial capital to facilitate moving, they also might face steeper psychic costs to moving locations relative to unemployed persons due to their greater attachment to the current location.

Labor force switching costs Labor force switching costs are modeled in a similar way as moving costs. Let k index the previous labor supply choice (0 for out of the labor force, 1 for in the labor force), which is embedded in Z_{it} . The labor force switching costs are allowed to vary by entry or exit and have the following form for each:

$$\Xi_1(Z_{it}) = (\theta_8 + \theta_9 \text{age}_{it} + \theta_{10} \text{age}_{it}^2 + \theta_{11} \tau_{ir}) 1\{k = 0\} \quad (\text{A.13})$$

$$\Xi_0(Z_{it}) = (\theta_{12} + \theta_{13} \text{age}_{it} + \theta_{14} \text{age}_{it}^2 + \theta_{15} \tau_{ir}) 1\{k = 1\} \quad (\text{A.14})$$

As with the moving costs, the intercepts θ_8 and θ_{12} are fixed costs of switching employment status, while the other parameters capture the fact that switching costs increase with age (but potentially at a decreasing rate) and that switching costs may be unobserved. As with the moving costs, the

⁴²[Davies, Greenwood, and Li \(2001\)](#) also include moving costs in a conditional logit analysis of migration.

⁴³Those who were previously out of the labor force serve as the reference group.

signs of the θ 's are freely estimated. The fixed costs and linear age terms are expected to have a negative sign, while the θ 's associated with the quadratic age terms are expected to be positive.⁴⁴

A.2 Further details on identification of the model's parameters

This section informally discusses identification of various parameters of the model.⁴⁵ As in all dynamic discrete choice models, only differences in utility are identified. I choose to normalize all parameters relative to labor force participation in the first location ($d_{it} = (1, 1)$). The scale of utility is normalized by assuming payoff shocks are drawn from a Type I extreme value distribution. The discount factor β is not identified, so I set it equal to 0.9.

I now present a more detailed discussion of the identification of each of the model's parameters: the parameters of the earnings equation, employment probabilities, and flow utilities, and the population parameters of unobserved productivity and preferences. As with any causal analysis using observational data, identification relies on a set of exclusion restrictions.

A.2.1 Identification of earnings and employment parameters

The vector of earnings parameters is identified from variation in earnings across locations, time, and levels of work experience. These parameters are consistently estimated using OLS as part of the EM algorithm. Within-person serial correlation in earnings identifies the unobserved type coefficient. That is, those who have earnings that are persistently higher than would be predicted by their observable characteristics are labeled as “high” earnings types.

Job destruction and job offer probabilities (π_{ilrt}) are identified non-parametrically from transitions between employment states. This is possible because of the assumption that employment happens according to a lottery with pre-commitment. As with earnings, within-person serial correlation in employment identifies the unobserved type dummy.

⁴⁴Previous employment status is not included in the switching costs so as to maintain clear interpretation of the search cost parameter γ_2 in (A.10).

⁴⁵See [Magnac and Thesmar \(2002\)](#) for a formal discussion of identification in dynamic discrete choice models.

A.2.2 Identification of utility parameters

The search cost parameter γ_2 is identified from the share of labor force participants that are unemployed. This share is in turn identified through the employment probabilities $\pi_{i\ell rt}$, which are identified from transitions between employment states. It is not possible to identify separate values of γ_2 for each type, because γ_2 depends on the employment probabilities, which themselves are type-specific.

Parameters in the moving cost equation (Δ_ℓ) are identified from variation between the observed characteristics of movers and the probability of moving, along with the assumption that moving costs are symmetric (i.e. a move from Boston to Chicago has the same cost as a move from Chicago to Boston). Specifically, variation in the origin and destination of moves identifies the distance parameters, and variation in the ages of movers identifies the age parameters. Variation in the previous employment status of movers identifies the employment parameters. As with earnings and employment probabilities, serial correlation in moves—compared to what would be predicted given observables—identifies the type dummy coefficient in the moving cost equation.

Switching cost parameters Ξ_j are identified from the individual's observed characteristics and serial correlation in labor force entry and exit. However, these switching costs cannot be separately identified from home production benefits and local amenities because the set of all three is linearly dependent. Thus, identification is only possible under either a symmetry assumption or by taking the difference in the costs. I choose the latter because there is no theoretical reason for why the entry and exit costs should be symmetric. The results presented hereafter represent the cost of labor force entry net of labor force exit, because the utility of labor force participation is the baseline alternative.

Identification of the expected earnings coefficient in the flow utility of employment requires variation in earnings that is excluded from the flow utility equation. I make use of two such exclusion restrictions. The first is variation in work experience, and the second is variation in mean earnings across time periods within each location. These exclusion restrictions allow me to distinguish between expected earnings and amenities.

I now discuss the implications of the exclusion restrictions for identification of the expected earnings coefficient. The work experience exclusion restriction hinges on the assumption that work

experience is uncorrelated with time-varying amenities. This is a reasonable assumption there is no reason to think that time-varying amenities in a given location (e.g. crime, air pollution) would be correlated with the level of work experience in that location. The time dummy exclusion restriction implies that amenities are fixed over time. In the short run, this is likely to hold, as amenities that vary over time within a location (e.g. crime or economic development) are much less volatile than local labor market conditions.⁴⁶ Given that this model focuses on a 10-year period, this is a reasonable exclusion restriction.

Finally, the population proportion of each unobserved type, denoted $\bar{\pi}_r$, is directly identified from the frequency of individuals with each particular type label.

A.3 Further details on estimation of the model

This section explains in detail the various steps to estimate the model's parameters.

A.3.1 Employment probabilities

This subsection details the functional form and specification for the logit models from which the employment probabilities are derived. Each of the estimated employment probabilities can be summarized in words. $\hat{\lambda}_{i\ell rt}$ measures the probability that an individual was not employed in the previous period and is employed in the current period in the same location. Likewise, $\hat{\delta}_{i\ell rt}$ measures job destruction, i.e. the probability that an individual is not employed in the current period but was employed in the current location in the previous period. Finally, $\hat{\lambda}_{i\ell rt}^e$ and $\hat{\lambda}_{i\ell rt}^u$ measure the probability of employment in a new location given previous employment status e or u .

The logit equation for $\hat{\delta}_{i\ell rt}$ and $\hat{\lambda}_{i\ell rt}^e$ is estimated conditional on choosing to supply labor in the current period and having been employed in the previous period.

$$\Pr[y_{it} = (e, \ell) | d_{it} = (1, \ell), y_{it-1} = (e, \cdot)] = \frac{\exp(\Theta_1)}{1 + \exp(\Theta_1)} \quad (\text{A.15})$$

⁴⁶For instance, over the 11-year period from 2000-2010, annual crime rates in Washington, D.C. for a variety of crimes remained mostly stable. See http://www.dccrimepolicy.org/Briefs/images/Volatility-Brief-3-10-11_1.pdf for more details.

where

$$\Theta_1 = \mu_{1\ell}^e + \mu_2^e \text{UR}_{\ell t-1} + \mu_3^e G(x_{it}) + \mu_4^e \tau_{ir} + \mu_5^e 1 \{y_{it-1} = (e, \ell')\}$$

and where $\text{UR}_{\ell t-1}$ is the lagged unemployment rate in location ℓ and $G(\cdot)$ is a quadratic polynomial. The excluded category is $1 \{y_{it-1} = (e, \ell)\}$. A similar regression can be estimated conditional on non-employment in the previous period.

$$\Pr[y_{it} = (e, \ell) | d_{it} = (1, \ell), y_{it-1} = (\{u, n\}, \cdot)] = \frac{\exp(\Theta_2)}{1 + \exp(\Theta_2)} \quad (\text{A.16})$$

where

$$\Theta_2 = \mu_{1\ell}^u + \mu_2^u \text{UR}_{\ell t-1} + \mu_3^u G(x_{it}) + \mu_4^u \tau_{ir} + \mu_5^u 1 \{y_{it-1} = (\{u, n\}, \ell')\}$$

The excluded category in (A.16) is $1 \{y_{it-1} = (\{u, n\}, \ell)\}$. Non-stationarity in the $\pi_{i\ell rt}$'s is accounted for through the evolution of the local unemployment rate.

Conditioning (A.15) and (A.16) on labor force participants is crucial, because in the model individuals do not exogenously transition between labor force participation states—they only exogenously transition between employment states (conditional on participating in the labor force).

It then follows that

$$1 - \hat{\delta}_{i\ell rt} = \frac{\exp(\hat{\mu}_{1\ell}^e + \hat{\mu}_2^e \text{UR}_{\ell t-1} + \hat{\mu}_3^e G(x_{it} + \hat{\mu}_4^e \tau_{ir}))}{1 + \exp(\hat{\mu}_{1\ell}^e + \hat{\mu}_2^e \text{UR}_{\ell t-1} + \hat{\mu}_3^e G(x_{it} + \hat{\mu}_4^e \tau_{ir}))} \quad (\text{A.17})$$

$$\hat{\lambda}_{i\ell rt}^e = \frac{\exp(\hat{\mu}_{1\ell}^e + \hat{\mu}_2^e \text{UR}_{\ell t-1} + \hat{\mu}_3^e G(x_{it}) + \hat{\mu}_4^e \tau_{ir} + \hat{\mu}_5^e)}{1 + \exp(\hat{\mu}_{1\ell}^e + \hat{\mu}_2^e \text{UR}_{\ell t-1} + \hat{\mu}_3^e G(x_{it}) + \hat{\mu}_4^e \tau_{ir} + \hat{\mu}_5^e)} \quad (\text{A.18})$$

$$\hat{\lambda}_{i\ell rt}^u = \frac{\exp(\hat{\mu}_{1\ell}^u + \hat{\mu}_2^u \text{UR}_{\ell t-1} + \hat{\mu}_3^u G(x_{it}) + \hat{\mu}_4^u \tau_{ir})}{1 + \exp(\hat{\mu}_{1\ell}^u + \hat{\mu}_2^u \text{UR}_{\ell t-1} + \hat{\mu}_3^u G(x_{it}) + \hat{\mu}_4^u \tau_{ir})} \quad (\text{A.19})$$

$$\hat{\lambda}_{i\ell rt}^u = \frac{\exp(\hat{\mu}_{1\ell}^u + \hat{\mu}_2^u \text{UR}_{\ell t-1} + \hat{\mu}_3^u G(x_{it}) + \hat{\mu}_4^u \tau_{ir} + \hat{\mu}_5^u)}{1 + \exp(\hat{\mu}_{1\ell}^u + \hat{\mu}_2^u \text{UR}_{\ell t-1} + \hat{\mu}_3^u G(x_{it}) + \hat{\mu}_4^u \tau_{ir} + \hat{\mu}_5^u)} \quad (\text{A.20})$$

A.3.2 Flow utility parameters

This subsection provides additional details for how the flow utility parameters are estimated. The main idea is that the recursive Bellman equation can be reduced to a static problem by making

use of conditional choice probabilities (CCPs) and the property of finite dependence. Throughout this section, I suppress the individual subscript i and unobserved type subscript r for expositional purposes.

Conditional choice probabilities I first describe how CCPs are employed. To do so, I define the following equation, which is a rewritten form of (3.2). The choice-specific value function $v_{ij\ell t}$ is defined as the flow payoff of choosing (j, ℓ) minus $\varepsilon_{ij\ell t}$ plus future utility assuming that the optimal decision is made in every period from $t + 1$ on.

$$\begin{aligned} v_{ij\ell t}(Z_{it}) &= u_{ij\ell t}(Z_{it}) + \beta \int V_{it+1}(Z_{it+1}) dF(Z_{it+1}|Z_{it}) \\ &= u_{ij\ell t}(Z_{it}) + \beta \int \mathbb{E}_{\varepsilon} \max_{k,m} \{v_{ikmt+1}(Z_{it+1}) + \varepsilon_{ikmt+1}\} dF(Z_{it+1}|Z_{it}) \end{aligned} \quad (\text{A.21})$$

Equation (A.21) shows that, by definition, the value function $V_{t+1}(Z_{t+1})$ is equivalent to the $\mathbb{E} \max$ of the conditional value functions in period $t + 1$ plus the ε_{t+1} 's.

When the ε 's are assumed to be Type I extreme value, equation (A.21) simplifies to

$$v_{j\ell t}(Z_t) = u_{j\ell t}(Z_t) + \beta \int \ln \left(\sum_k \sum_m \exp(v_{kmt+1}(Z_{t+1})) \right) dF(Z_{t+1}|Z_t) + \beta \bar{\gamma} \quad (\text{A.22})$$

where $\bar{\gamma}$ is Euler's constant, the mean of a standard Type I extreme value distribution (McFadden, 1974; Rust, 1987). Thus, the $\mathbb{E} \max$ is the natural log of the sum of the exponentiated conditional value functions, plus Euler's constant.⁴⁷

I will now show how (A.22) can be manipulated to admit CCPs. First, multiply and divide by the exponentiated conditional value function associated with a given choice alternative (e.g.

⁴⁷This follows from the fact that the Type I extreme value distribution has a closed-form CDF. The mean of the distribution is Euler's constant. If the ε_t 's were assumed to be normally distributed, the $\mathbb{E} \max$ term would not have a closed form, for the same reason that the Normal CDF does not have a closed form. The CCP method works for any distribution of ε , but requires numerical integration or simulation methods for distributions that are outside of the Generalized Extreme Value family.

(j', ℓ') , $\exp(v_{j'\ell'_{t+1}}(Z_{t+1}))$, to get

$$\int V_{t+1}(Z_{t+1}) dF(Z_{t+1}|Z_t) = \int \ln \left(\frac{\exp(v_{j'\ell'_{t+1}}(Z_{t+1}))}{\exp(v_{j'\ell'_{t+1}}(Z_{t+1}))} \right) dF(Z_{t+1}|Z_t) + \bar{\gamma} \quad (\text{A.23})$$

$$= \int \left[v_{j'\ell'_{t+1}}(Z_{t+1}) + \ln \left(\frac{\sum_k \sum_m \exp(v_{kmt+1}(Z_{t+1}))}{\exp(v_{j'\ell'_{t+1}}(Z_{t+1}))} \right) \right] dF(Z_{t+1}|Z_t) + \bar{\gamma} \quad (\text{A.24})$$

$$= \int [v_{j'\ell'_{t+1}}(Z_{t+1}) - \ln p_{j'\ell'_{t+1}}(Z_{t+1})] dF(Z_{t+1}|Z_t) + \bar{\gamma} \quad (\text{A.25})$$

Comparing (A.21) with (A.25) shows that, for any choice alternative (j', ℓ') , the future value function is equal to the conditional value function $v_{j'\ell'_{t+1}}$ minus the log probability of choosing (j', ℓ') . This log probability is the conditional choice probability, and can in principle be recovered non-parametrically from the data. The CCP method pares down the number of future-period conditional value functions from $2L$ to 1.

While it is helpful that the number of conditional value functions has decreased, the value function as currently expressed still has a recursive structure. In mathematical terms, $v_{j'\ell'_{t+1}}(Z_{t+1})$ in (A.25) is a function of V_{t+2} , which is a function of V_{t+3} , etc. In order to eliminate this recursive structure and the need to use backward recursion to solve the model, I make use of the property of finite dependence.

Finite dependence Finite dependence is based on the fact that in discrete choice models only differences in utility (or, in dynamic models, differences in the present value of utility) matter in estimation, e.g. $v_{j'\ell'_t} - v_{0\ell'_t}$. Hence, it is possible to express the value function for choosing (j', ℓ') in period t in terms of a sequence of decisions up to N periods ahead, then create a corresponding sequence of decisions for choosing the base alternative $(0, \ell)$ in period t such that after N periods the value functions are the same and can cancel out. The key insight is that this sequence of decisions need not be optimal.⁴⁸

⁴⁸For other studies using finite dependence to aid estimation, see Altuğ and Miller, 1998; Arcidiacono and Miller, 2011; Bishop, 2012; Coate, 2013; Arcidiacono, Aucejo, Maurel, and Ransom, 2016; Arcidiacono and Miller, 2019; Gayle, 2018; and Humphries, 2018.

In the case where the choice outcomes correspond to the choice alternatives, the following sequences could be used for all (j', ℓ') to create a cancellation in period $t + 3$:

- $v_{j'\ell'_t}$ path: choose $d_t = (j', \ell')$; $d_{t+1} = (0, \ell')$; $d_{t+2} = (0, \ell)$
- $v_{0\ell_t}$ path: choose $d_t = (0, \ell)$; $d_{t+1} = (j', \ell)$; $d_{t+2} = (0, \ell)$

where ℓ is the location in period $t - 1$. In both cases, the states in period $t + 3$ are one additional year of work experience, three additional years of age, and previous decision equal to non-participation in location ℓ . The value function $V_{t+3}(Z_{t+3})$ is thus the same for both and vanishes when the standard utility normalization is applied.

In the case where labor market outcomes are stochastic, however, inducing the cancellation of the future value terms is not as straightforward. To illustrate how the setup proceeds in this case, recall equation (A.25), rewritten below in conserved notation:

$$\mathbb{E}_t V_{t+1}(Z_{t+1}) = \mathbb{E}_t [v_{j'\ell'_{t+1}}(Z_{t+1}) - \ln(p_{j'\ell'_{t+1}}(Z_{t+1}))] + \bar{\gamma}$$

The key idea is that this equality holds for a weighted sum of $v_{j'\ell'_{t+1}}$'s such that the weights add up to unity:

$$\begin{aligned} \mathbb{E}_t V_{t+1}(Z_{t+1}) &= \mathbb{E}_t [v_{j'\ell'_{t+1}}(Z_{t+1}) - \ln(p_{j'\ell'_{t+1}}(Z_{t+1}))] + \bar{\gamma} \\ &= \sum_{(k,m) \in \mathcal{J}} \omega_{(k,m)} \{ \mathbb{E}_t [v_{kmt+1}(Z_{t+1}) - \ln(p_{kmt+1}(Z_{t+1}))] + \bar{\gamma} \} \\ \text{s.t. } \sum_{(k,m) \in \mathcal{J}} \omega_{(k,m)} &= 1 \end{aligned} \tag{A.26}$$

In the application below, the $\omega_{(k,m)}$'s are functions of the current and future employment probabilities.

Figure A4 shows how the finite dependence structure works in the case of stochastic choice outcomes. It depicts the choice sequences for $v_{j'\ell'_t}$ and $v_{0\ell_t}$ conditional on the previous choice outcome y_{t-1} . Because of the random nature of employment outcomes, the individual must take expectations over all possible outcomes. Thus, each period of labor force participation induces two outcomes, which are depicted in tree form in Figure A4 (recall that $\pi_{\ell_t} = 0$ for the non-participation

decision). Decisions are depicted by boxes, and outcomes are depicted by nodes. Probabilities are written next to edges connecting the nodes.

The top branches of each sub-tree in the diagram have the same state variables in $t + 3$. However, because the individual must take expectations over the future employment outcomes, cancellation of these terms is not possible except for the case of degenerate employment probabilities or the case where $\pi_{\ell'_t} = \pi_{\ell_{t+1}}$. This equality does not hold in general.

In order to induce the cancellation, I make use of the insights provided by equation (A.26). The diagram for this case is provided in Figure A5. The difference is that now the $t + 1$ decision in the expression for $v_{0\ell_t}$ is a weighted sum of $d_{t+1} = (1, \ell)$ and $d_{t+1} = (0, \ell)$. The ω 's are pushed through to the $t + 3$ states as with the other probabilities in the tree.

Cancellation is possible by solving for the ω 's that make the top branches of each tree equal:

$$\pi_{\ell'_t} V_{t+3} = \omega_{(1,\ell)} \pi_{\ell_{t+1}} V_{t+3} \quad (\text{A.27})$$

Solving (A.27) for ω gives

$$\omega_{(1,\ell)} = \frac{\pi_{\ell'_t}}{\pi_{\ell_{t+1}}} \quad (\text{A.28})$$

A similar solution strategy can be used for the bottom branches of each tree, with the same value of ω being true for both cases.

Putting everything together, the final equation for the differenced conditional value function

expression is then (suppressing i and r subscripts and assuming $j' = 1$):

$$\begin{aligned}
v_{j'\ell_t} - v_{0\ell_t} = & \pi_{\ell_t} u_{\ell_t}^e(Z_t) + (1 - \pi_{\ell_t}) u_{\ell_t}^u(Z_t) - u_{\ell_t}^n(Z_t) \\
& + \beta [\pi_{\ell_t} u_{\ell_{t+1}}^n(Z_{t+1}^1) - \pi_{\ell_t} \ln p_{0\ell_{t+1}}(Z_{t+1}^1) \\
& + (1 - \pi_{\ell_t}) u_{\ell_{t+1}}^n(Z_{t+1}^2) - (1 - \pi_{\ell_t}) \ln p_{0\ell_{t+1}}(Z_{t+1}^2) \\
& - \pi_{\ell_t} u_{\ell_{t+1}}^e(Z_{t+1}^3) \\
& - \left(\frac{\pi_{\ell_t}(1 - \pi_{\ell_{t+1}})}{\pi_{\ell_{t+1}}} \right) u_{\ell_{t+1}}^u(Z_{t+1}^3) - \left(1 - \frac{\pi_{\ell_t}}{\pi_{\ell_{t+1}}} \right) u_{\ell_{t+1}}^n(Z_{t+1}^3) \\
& + \left(\frac{\pi_{\ell_t}}{\pi_{\ell_{t+1}}} \right) \ln p_{1\ell_{t+1}}(Z_{t+1}^3) + \left(1 - \frac{\pi_{\ell_t}}{\pi_{\ell_{t+1}}} \right) \ln p_{0\ell_{t+1}}(Z_{t+1}^3)] \\
& + \beta^2 [\pi_{\ell_t} u_{\ell_{t+2}}^n(Z_{t+2}^4) - \pi_{\ell_t} \ln p_{0\ell_{t+2}}(Z_{t+2}^4) \\
& + (1 - \pi_{\ell_t}) u_{\ell_{t+2}}^n(Z_{t+2}^5) - (1 - \pi_{\ell_t}) \ln p_{0\ell_{t+2}}(Z_{t+2}^5) \\
& - \pi_{\ell_t} u_{\ell_{t+2}}^n(Z_{t+2}^6) + \pi_{\ell_t} \ln p_{0\ell_{t+2}}(Z_{t+2}^6) \\
& - \left(\frac{\pi_{\ell_t}(1 - \pi_{\ell_{t+1}})}{\pi_{\ell_{t+1}}} \right) u_{\ell_{t+2}}^n(Z_{t+2}^7) + \left(\frac{\pi_{\ell_t}(1 - \pi_{\ell_{t+1}})}{\pi_{\ell_{t+1}}} \right) \ln p_{0\ell_{t+2}}(Z_{t+2}^7) \\
& - \left(1 - \frac{\pi_{\ell_t}}{\pi_{\ell_{t+1}}} \right) u_{\ell_{t+2}}^n(Z_{t+2}^8) + \left(1 - \frac{\pi_{\ell_t}}{\pi_{\ell_{t+1}}} \right) \ln p_{0\ell_{t+2}}(Z_{t+2}^8)]
\end{aligned} \tag{A.29}$$

where the integrals over the future state variables have been suppressed for notational simplicity. Superscripts on the state variables Z denote different sets of states.⁴⁹

Equation (A.29) is a complex formula that includes employment probabilities, flow utility parameters, and log CCPs. However, it is a linear function of all structural parameters which greatly simplifies the estimation. Most importantly, there is no need to use backward recursion in the estimation procedure.

For non-employment alternatives, the finite dependence formula written in equation (A.29) is

⁴⁹ Additionally, the state dependence of the employment probabilities π_{ℓ_t} and $\pi_{\ell_{t+1}}$ is also suppressed for simplicity. π_{ℓ_t} is always evaluated at Z_t while $\pi_{\ell_{t+1}}$ is always evaluated at Z_{t+1}^3 .

much simpler (because $pi_{\ell t} = 0$ when $j = 0$ for all ℓ and t):

$$\begin{aligned}
v_{j'\ell t}(Z_t) - v_{0\ell t}(Z_t) = & u_{\ell' t}^n(Z_t) - u_{\ell t}^n(Z_t) + \\
& \beta \left[(u_{\ell' t+1}^n(\{0, \ell'\}, x_t) - \ln p_{0\ell' t+1}(\{0, \ell'\}, x_t)) \right. \\
& \left. - u_{\ell t+1}^n(\{0, \ell\}, x_t) + \ln p_{0\ell t+1}(\{0, \ell\}, x_t) \right] + \\
& \beta^2 \left[u_{\ell' t+2}^n(\{0, \ell'\}, x_t) - \ln p_{0\ell' t+2}(\{0, \ell'\}, x_t) \right. \\
& \left. - u_{\ell t+2}^n(\{0, \ell\}, x_t) + \ln p_{0\ell t+2}(\{0, \ell\}, x_t) \right]
\end{aligned} \tag{A.30}$$

Figures A4 and A5 have illustrated how finite dependence can be used even in models where choice outcomes are not included in the choice set. This method can be used in a variety of other discrete choice applications where stochastic choice outcomes might not be aligned with deterministic choices.

Using CCPs and finite dependence, the optimization problem has been reduced from a backward recursion problem to a simple multi-stage static estimation problem with an adjustment term comprised of CCPs, current and future flow utilities, and employment probabilities, resulting in impressive computational gains that make possible the estimation of the model.

Integrating out local labor market shocks When making decisions about the future, agents need to form expectations over the evolution of the labor market conditions in each location. This is outlined in equations (A.2) and (A.4). However, the evolution of these labor market conditions also enters the future value term associated with each alternative. Because this future value term is non-linear, the future labor market shocks need to be integrated out of the value function. Furthermore, because the shock in *each* location enters the choice probability associated with any given location, the dimension of this integral is on the order of double the number of locations.⁵⁰ With many locations, the only way to compute the integral is using Monte Carlo techniques.

The structure of the forecasting problem further underscores the advantages in using CCPs and finite dependence to estimate the flow utility parameters. If estimating the parameters using the full solution (backwards recursion) method, the researcher would be required to evaluate the value

⁵⁰ L of the $2L$ dimensions correspond to the earnings AR(1) shocks ζ_t and the other L dimensions correspond to the unemployment rate AR(1) shocks ξ_t .

function at each realization of the labor market shocks and integrate accordingly. To make the backwards recursion tractable, interpolation methods (Keane and Wolpin, 1994) or simplification of the state space (Kennan and Walker, 2011) would have to be used.

In my case, I can use the finite dependence assumption to exactly rewrite the value function in terms of one- and two-period ahead CCPs and flow payoffs. This only requires integration of the relevant CCPs and employment probabilities, of which there are only nine for each choice alternative (see equation A.29).

Formally, an example of the time- t expectation of one of the log CCPs (choosing alternative $(0, \ell')$) is written as follows:

$$E_t [\ln (p_{0\ell't+1} (\xi_{t+1}, \zeta_{t+1})) | Z_t] = \int \ln p_{0\ell't+1} (\xi_{t+1}, \zeta_{t+1}) dF (\xi, \zeta) \quad (\text{A.31})$$

where ξ_{t+1} and ζ_{t+1} are respectively L -dimensional vectors of earnings and employment shocks in period $t + 1$. f is the density of a multivariate normal distribution with mean 0 and covariance Ψ .⁵¹

The integral in (A.31) is of dimension $2L$ and thus needs to be estimated using Monte Carlo methods. This is done by drawing D draws from the $N(0, \Psi)$ density, plugging them into the CCPs, and averaging over the draws as written below:

$$\int \ln p_{0\ell't+1} (\xi_{t+1}, \zeta_{t+1}) dF (\xi, \zeta) \approx \frac{1}{D} \sum_{d=1}^D \ln p_{0\ell't+1} (\xi_d, \zeta_d) \quad (\text{A.32})$$

where (ξ_d, ζ_d) is the d th draw from f .

For integration of the two-period-ahead CCPs, the variance of f is modified to account for uncertainty in the one-period-ahead outcomes. In this case, the variance matrix of f is

$$\Psi + \Psi \odot RR' \quad (\text{A.33})$$

where \odot is the element-wise (Hadamard) product and R is a $2L \times 1$ vector of autocorrelation parameters corresponding to earnings or employment forecasting (ρ_1 or $\phi_{1\ell}$). The result in (A.33) comes about because the forecasting shocks are assumed to be normally distributed and independent over

⁵¹ Ψ is estimated by computing the covariance of the AR(1) residuals for all equations in both AR(1) systems.

time.

A.3.3 Details on joint likelihood function and the EM algorithm

This subsection outlines the exact functional form of each of the components of the likelihood function. The main idea is that each of the components of the model introduced in Section 3 contains an intercept for unobserved type, which means that estimation is not separable across components. I explain how to use the EM algorithm to obtain parameter estimates of the model. The EM algorithm is a sequential algorithm that allows me to break the dependence of any model component on the rest of the components. Estimation reduces to an iterative procedure where each component of the model can be estimated separately.⁵²

The overall log likelihood of the model in the presence of unobserved heterogeneity is

$$L = \sum_i \ln \left(\sum_{r=1}^R \bar{\pi}_r \mathcal{L}_{d,i|r} \mathcal{L}_{w,i|r} \mathcal{L}_{\pi,i|r} \right) \quad (\text{A.34})$$

where $\mathcal{L}_{d,i|r}$ denotes the likelihood contribution of the choice parameters conditional on being unobserved type r , $\mathcal{L}_{w,i|r}$ the earnings likelihood contribution, and $\mathcal{L}_{\pi,i|r}$ the employment probability contribution.

$$L = \sum_i \ln \left(\sum_{r=1}^R \bar{\pi}_r \prod_j \prod_\ell \prod_t \left\{ [P_{ij\ell rt} \Lambda_{i\ell rt} h_{i\ell rt}]^{d_{ij\ell t}} \right\}^{1[j=1]} [P_{ij\ell rt}^{d_{ij\ell t}}]^{1[j=0]} \right) \quad (\text{A.35})$$

where the following hold:

- P is a multinomial logit function:

$$P_{ij\ell rt} = \frac{\exp(\cdot)}{\sum_{k=1}^{J \times L} \exp(\cdot)} \quad (\text{A.36})$$

- Λ is the likelihood associated with an individual's employment probability, which contributes to the likelihood only when $j = 1$ (i.e. labor is supplied), and which depends on the prior

⁵²For further details on the EM algorithm, see Arcidiacono and Jones (2003) and Arcidiacono and Miller (2011). The algorithm is used in Arcidiacono (2004); James (2012); Arcidiacono, Aucejo, Maurel, and Ransom (2016); Humphries (2018); and others.

labor market outcome. Λ is a product of two binary logit likelihoods.

$$\Lambda_{i\ell rt} = \left[\pi_{i\ell rt}^{1[y_{i\ell t}=e]} (1 - \pi_{i\ell rt})^{1[y_{i\ell t} \neq e]} \right]^{1[y_{i\ell t-1}=e]} \left[\pi_{i\ell rt}^{1[y_{i\ell t}=e]} (1 - \pi_{i\ell rt})^{1[y_{i\ell t} \neq e]} \right]^{1[y_{i\ell t-1} \neq e]} \quad (\text{A.37})$$

where $\pi_{i\ell rt}$ is as defined in (A.3) and where y denotes employment outcome.

- h is an individual's wage likelihood, which contributes to the likelihood only when $j = 1$ and the individual is employed with valid earnings. Under the assumption that the measurement error in wages is normally distributed (see Equation A.1), the likelihood is given by

$$h_{i\ell rt} = \frac{1}{\sigma_\eta} \phi^h \left(\frac{\ln w_{i\ell t} - \psi_{0\ell t} - \psi_1 G(x_{it}) - \psi_2 \tau_{ir}}{\sigma_\eta} \right) \quad (\text{A.38})$$

where $\phi^h(\cdot)$ is the standard normal density function.

Using Bayes' rule, the probability that i is of unobserved type r is defined as follows:

$$q_{ir} = \frac{\bar{\pi}_r \mathcal{L}_{d,i|r} \mathcal{L}_{w,i|r} \mathcal{L}_{\pi,i|r}}{\sum_{r'=1}^R \bar{\pi}_{r'} \mathcal{L}_{d,i|r'} \mathcal{L}_{w,i|r'} \mathcal{L}_{\pi,i|r'}} \quad (\text{A.39})$$

It then follows that the population unobserved type probabilities are given by

$$\bar{\pi}_r = \frac{1}{N} \sum_i q_{ir} \quad (\text{A.40})$$

The key insight of (A.39) is that (A.34) can be rewritten as

$$\tilde{L} = \sum_i \sum_{r=1}^R \{ q_{ir} \ln \mathcal{L}_{d,i|r} + q_{ir} \ln \mathcal{L}_{w,i|r} + q_{ir} \ln \mathcal{L}_{\pi,i|r} \} \quad (\text{A.41})$$

where the first order conditions of \tilde{L} are equal to the first order conditions of L in (A.34). This equivalence at the first order conditions enables implementation of the EM algorithm, which iterates on the first order conditions until convergence. The convergence point is the solution to both (A.34) and (A.41). Most importantly, (A.41) is additively separable in each likelihood, so each likelihood can be estimated separately.

Each likelihood contribution differs by type through the inclusion of a type dummy in each of the separate likelihoods. The algorithm iterates on the following steps:

1. Given estimates of the earnings parameters, employment probabilities, structural flow utilities, update the q_{ir} 's according to equation (A.39) and $\bar{\pi}_r$'s according to (A.40).
2. Estimate the earnings parameters and employment probabilities by weighted OLS and a pair of weighted binary logits, respectively, where the q_{ir} 's are used as weights.
3. Estimate the CCPs using a weighted flexible multinomial logit model, where the q_{ir} 's are used as weights.
4. Calculate the expected future value terms along the finite dependence paths, using the estimated earnings parameters, the employment probabilities, and the CCPs as inputs. Integrate over future local labor market shocks.
5. Estimate the flow utility parameters in the structural choice model. This amounts to estimating a weighted multinomial logit with an offset term containing the future value terms computed in Step 4, where the q_{ir} 's are used as weights.
6. Repeat until convergence

Step 1 is referred to as the Expectation- or E-step because the researcher integrates over the type-conditional likelihoods, and Steps 2–5 constitute the Maximization- or M-step because the researcher maximizes the type-conditional likelihoods.

A.4 Calculating moving costs and amenity values

This section details the calculation of the moving cost and amenity values. For simplicity, consider only the location dimension of choice and only the amenity and moving cost components of the the flow utility. That is, suppose that the flow utility of i for choosing location j in period t is

$$u_{ijt} = \alpha_j + \gamma_0 \ln w_{ijt} + \theta_0 \cdot 1[d_{it-1} \neq j] + \varepsilon_{ijt} \quad (\text{A.42})$$

where $1[d_{it-1} \neq j]$ indicates that i chose a location different from j in the previous period, i.e. θ_0 is the parameter representing the fixed cost of moving.

A.4.1 Moving costs

Moving costs are paid once, rather than on a per-period basis. Because the model is dynamic, a natural question to ask is, “what is the present value of the increase in (flow) earnings required to make the person indifferent between moving and not moving, holding fixed all other aspects of utility?”

Assume that the person has T periods left in his working life, and that a move is made in period τ . Denote w as the status-quo earnings and w' as the earnings received after moving.

If the person moves, the present value stream of utility is

$$PV_{\text{move}} = \sum_{t=0}^{\tau-1} \beta^t u(w) + \beta^\tau u(w', \text{move}) + \sum_{t=\tau+1}^T \beta^t u(w'). \quad (\text{A.43})$$

And if the person does not move, the present value stream of utility is

$$PV_{\text{stay}} = \sum_{t=0}^{\tau-1} \beta^t u(w) + \beta^\tau u(w) + \sum_{t=\tau+1}^T \beta^t u(w). \quad (\text{A.44})$$

Setting the two equal and canceling out the first $\tau - 1$ periods gives

$$\begin{aligned} \beta^\tau u(w', \text{move}) + \sum_{t=\tau+1}^T \beta^t u(w') &= \beta^\tau u(w) + \sum_{t=\tau+1}^T \beta^t u(w) \\ \beta^\tau u(w', \text{move}) &= \beta^\tau u(w) + \sum_{t=\tau+1}^T \beta^t [u(w) - u(w')] \\ \beta^\tau [\gamma_0 \ln w' + \theta_0] &= \beta^\tau \gamma_0 \ln w + \sum_{t=\tau+1}^T \beta^t [\gamma_0 \ln w - \gamma_0 \ln w'] \\ \beta^\tau \left[\ln w' + \frac{\theta_0}{\gamma_0} \right] &= \beta^\tau \ln w + \sum_{t=\tau+1}^T \beta^t [\ln w - \ln w'] \\ -\frac{\theta_0}{\gamma_0} &= \sum_{t=\tau}^T \beta^{t-\tau} \left[\ln \left(\frac{w'}{w} \right) \right] \end{aligned} \quad (\text{A.45})$$

One can use a variety of numerical methods to solve the above equation for w'/w (and then subtract 1 to obtain a percentage change). To obtain the values reported in Table 7, I plug in the parameter estimates from Table 6, set T to be 65 minus the age, and set $\tau = 1$. Rather than use θ_0 in each cell of Table 7, I plug in the linear index implied by the parameter estimates, e.g. $\theta_0 + \theta_5$

for the fixed cost for an employed person of unobserved type 2, or $\theta_0 + \theta_5 + \theta_7$ for an employed person of unobserved type 1.

A.4.2 Amenity values

Because the amenity values are flow values, I can easily obtain their valuation by using a straightforward willingness to pay (WTP) formula (Koşar, Ransom, and van der Klaauw, 2020). As an example, I explain the calculation for living in one's state of birth.

Calculation of the WTP implies that the following indifference condition is satisfied:

$$\begin{aligned}
 u(w - WTP, \text{ in birth state}) &= u(w, \text{ not in birth state}) \\
 \gamma_0 \ln(w - WTP) + \gamma_3 &= \gamma_0 \ln(w) \\
 \gamma_0 [\ln(w - WTP) - \ln w] &= -\gamma_3 \\
 \ln\left(\frac{w - WTP}{w}\right) &= -\frac{\gamma_3}{\gamma_0} \\
 \frac{w - WTP}{w} &= \exp\left(-\frac{\gamma_3}{\gamma_0}\right) \\
 \frac{WTP}{w} &= 1 - \exp\left(-\frac{\gamma_3}{\gamma_0}\right) \\
 WTP &= \underbrace{\left[1 - \exp\left(-\frac{\gamma_3}{\gamma_0}\right)\right]}_{\text{fraction of flow earnings}} w
 \end{aligned} \tag{A.46}$$

A.4.3 Converting flow-equivalent values to net present values

The moving costs and amenity values are expressed in terms of a percentage of flow earnings. They can equivalently be expressed in terms of net present value. The formula to compute this is given below:

$$NPV = \sum_{t=\tau}^T \beta^{t-\tau} \frac{pct}{100} 12 \exp(\overline{\ln w}) \tag{A.47}$$

where pct is the percentage difference in flow earnings computed in (A.45) and (A.46), and $12 \exp(\overline{\ln w})$ is 12 times the exponential of the average monthly log earnings. For the numbers

reported in Panel A of Table 7, I use the same values of τ and T that are used in the calculation of the flow earnings equivalents above. I evaluate $12 \exp(\overline{\ln w})$ at different ages: \$34,530 (the unconditional sample average) for the fixed cost of moving, \$41,365 (the average among 39 year olds) for the average mover, and \$27,142 (the average among 25 year olds) for a young mover.

A.5 Further discussion of counterfactual simulations: where moving subsidy recipients relocate

I can use the model to analyze what happens when workers are given a moving subsidy. A similar policy has been proposed by Moretti (2012), and was introduced in the US House of Representatives as a bill sponsored by Rep. Tony Cardenas (H.R. 2755, 2015).⁵³ Because the moving subsidy is not tied to a particular destination location, I analyze where workers who accept the subsidy would choose to relocate. Table A9 shows estimates of a regression of the net migration probability (multiplied by 100) on a vector of location characteristics (amenities, earnings, job offer probability, and birth location proximity). The origin location is excluded from this regression. These regressions are run separately for each of the three origin cities and each of the two unobserved worker types.

Table A9 predicts that, all else equal, migrants will choose locations that are near their birth location, close to their origin location, and that have higher employment certainty and higher amenities.⁵⁴ This finding is consistent with Monras (2018), who finds that out-migration from heavily shocked areas was constant during the Great Recession, but that in-migration into heavily shocked areas decreased markedly. Interestingly, migrants value employment certainty much more than earnings, regardless of the origin city. The reason for this is that unemployment risk enters the flow utility of labor force participation twice (multiplied by the earnings and multiplied by the search cost and home production benefit), but earnings enters the flow utility once (multiplied by

⁵³These proposed policies focus on the fact that unemployment is an externality that should be internalized through subsidized migration. The model presented here does not include such externalities. However, such proposals abstract from preferences for amenities, which my model shows are important determinants of migration.

⁵⁴These results echo findings by Deryugina, Kawano, and Levitt (2018) who conclude that individuals displaced by Hurricane Katrina migrated to areas offering better economic opportunities, resulting in immediate wage gains. However, they also conclude that these wage gains were likely nominal (i.e. there were no utility gains), because housing prices for these people also increased by the same amount. My results show that migrants tend to choose places with higher amenities and that are closer to family (as proxied by birth location). This suggests that there can, in fact, be utility gains for displaced workers provided these workers are not native to the shocked location.

the unemployment risk). Hence, workers are more sensitive to unemployment uncertainty because it is costly to find a job when unemployed.

In summary, I emphasize that the response to each counterfactual shock is heterogeneous across locations. Specifically, cities with low amenities and low job-finding rates see the largest out-migration response to adverse shocks and favorable subsidies. Furthermore, areas with higher amenities and higher job-finding rates are the prime destinations for out-migrants. This heterogeneity underscores the difficulty in implementing migration policy that would have the intended consequence of inducing migration from high-unemployment areas to low-unemployment areas, because workers value amenities about the same as employment certainty and much more strongly than earnings.

A.6 Estimation subsample

The estimation subsample is restricted to non-Hispanic white males aged 18-55 who have completed schooling by the time of the first SIPP interview and who do not hold a bachelor's degree. The final estimation subsample comprises 16,648 males each averaging 3.03 annual observations. Earnings are computed as total monthly earnings across all jobs in the interview month. Observations with monthly earnings higher than \$22,000 or lower than \$400 are excluded from earnings estimates. The small percentage of workers with survey data containing missing or imputed monthly earnings are assigned a monthly estimate of annual earnings reported on their W-2 tax form. For complete details on sample selection, see Online Appendix Table [A1](#).

A.7 Population and Prices

I gather locational characteristics from a variety of sources. Using the Missouri Census Data Center's MABLE/Geocorr12 program, I form a crosswalk that maps every county to its Core Based Statistical Area (CBSA) as of 2009. The locational characteristics used in this analysis are population (in 2000) and prices (varying by year). Population is calculated by summing the population of each component county. If the individual does not live in a CBSA, his county population is used instead.

Locational prices come from the ACCRA-COLI data. This data, generously provided by

Christopher Timmins, contains quarterly information from 1990-2008 on six different categories of goods (groceries, housing, utilities, medical, transportation and miscellaneous) across a wide range of surveyed locations, both metropolitan and rural. I average prices over quarters and CBSA (since some large CBSAs have multiple price listings) to form an annual price index for each CBSA. For locations that are not included in a particular year, I assign each location to one of five population categories and then impute the price by assigning the average price of all other locations in the same state and population category. If the location still has no price information, I repeat the process but aggregate at the level of census region instead of state.

Multiple studies have found that housing prices listed in ACCRA are not good measures of true housing costs (e.g. DuMond, Hirsch, and Macpherson, 1999; Winters, 2009; Baum-Snow and Pavan, 2012). As a result, I follow Winters (2009) and use quality-adjusted gross rents from the 2005 American Community Survey (ACS) compiled by Ruggles et al. (2010). This consists of regressing log gross rents on a vector of housing characteristics and CBSA fixed effects. The housing price level of a given city is then the predicted average gross rents for that city evaluated at the mean housing characteristics for the entire sample. This price level is then included in place of the ACCRA housing price level when forming the price index in (A.48) below. For more details regarding the specific housing characteristics included in the analysis, see p. 636 of Winters (2009). It is also important to note that the ACS does not include location information for low populated areas. For locations that are not identifiable in the ACS, I use states instead of CBSAs. I exclude houses that are in an identifiable CBSA and repeat the process outlined above, assigning rural housing prices as state fixed effects plus average sample characteristics.

With location-specific prices in hand, I compute the price index according to Baum-Snow and Pavan (2012):

$$\text{INDEX}_j = \prod_g \left(\frac{p_g^j}{p_g^0} \right)^{s_g} \quad (\text{A.48})$$

where g indexes goods in the consumer's basket, p_g^j is the price of good g in location j , and s_g is the share of income on good g . In practice, g corresponds to the six categories of goods included in the ACCRA data: groceries, housing, utilities, transportation, health care and all other goods. I use the income shares provided by ACCRA which were computed using the Consumer Expenditure

Survey (CEX).

Once this is accomplished, I temporally deflate the indices using the CPI-U in 2000 and spatially deflate using the population-weighted average location in 2000. I then deflate earnings by dividing monthly earnings by this index.

Equation (A.48) is derived from an indifference relationship for identical workers in location j with utility function U over a vector of goods z (which is allowed to differ in price across locations):

$$\bar{v} = \max_z U(z) + \lambda \left[w_j - \sum_g p_g^j z_g \right]. \quad (\text{A.49})$$

Log-linearizing (A.49) around a mean location (indexed by 0) yields an equilibrium relationship in earnings adjusted for cost of living between locations j and 0, with s_g indicating the share of income spent on good z_g :

$$\ln(w_0) = \ln(w_j) - \sum_g s_g [\ln(p_g^j) - \ln(p_g^0)] \quad (\text{A.50})$$

Taking the exponential of both sides and rearranging terms yields equation (A.48).

A.8 SIPP Sample Design

The SIPP is a two-stage stratified random sample. The sampling frame is the Master Address File (MAF), which is a database maintained by the Census Bureau and used in other surveys such as the American Community Survey (ACS) and Decennial Censuses. The primary sampling unit (PSU) is one or more bordering counties. Within the PSU, addresses are divided into two groups: those with lower incomes and those with higher incomes. Addresses in the lower-income group are sampled at a higher rate.

Online Appendix Figures and Tables

Table A1: Sample selection

	Remaining Persons	Remaining Person-years
Non-Hispanic, non-college graduate white males in wave 1 of 2004 or 2008 SIPP panel	37,499	124,719
Drop those enrolled in school at any point of survey	30,410	102,740
Drop those outside of 18-55 age range at start of survey	20,153	65,836
Drop those who attrited from survey	20,148	58,320
Drop those missing link to administrative data	16,648	50,415
Final estimation sample	16,648	50,415

Table A2: Distribution of person-years

Years per person	Persons	Person-years
1	3,576	3,576
2	2,117	4,234
3	4,641	13,923
4	2,888	11,552
5	3,426	17,130
Final estimation sample	16,648	50,415

Table A3: Data sources

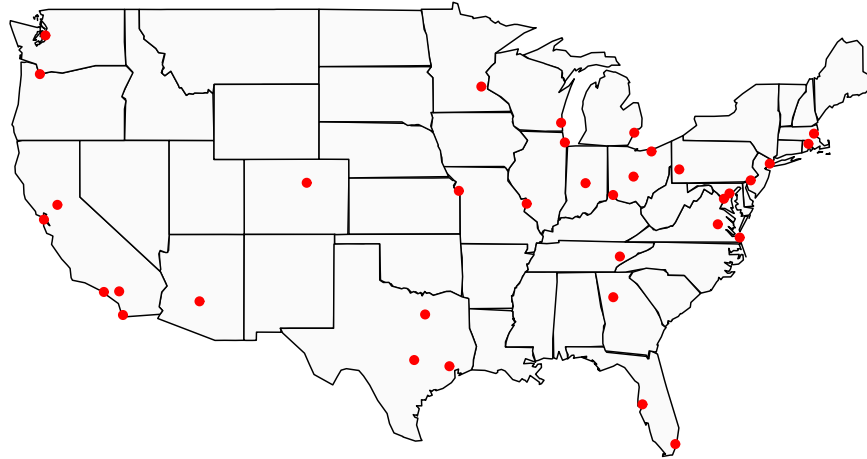
Data	Source	Years
Earnings and location & employment transitions	SIPP, 2004 and 2008 Panels	2004–2013
CBSA population	Census Bureau	2000
County unemployment rate	Bureau of Labor Statistics (BLS)	1990–2013
Local price level	American Chamber of Commerce Researchers Assoc. (ACCRA)	1990–2008

Table A4: Locations in the model

Location	Location
Atlanta , GA	San Diego , CA
Austin , TX	San Francisco , CA
Baltimore , MD	Seattle , WA
Boston , MA	St. Louis , MO
Chicago , IL	Tampa , FL
Cincinnati , OH	Virginia Beach, VA
Cleveland , OH	Washington , DC
Columbus , OH	New England Division small
Dallas , TX	New England Division medium
Denver , CO	Mid Atlantic Division small
Detroit , MI	Mid Atlantic Division medium
Houston , TX	E N Central Division small
Indianapolis , IN	E N Central Division medium
Kansas City , MO	W N Central Division small
Knoxville , TN	W N Central Division medium
Los Angeles , CA	S Atlantic Division small
Miami , FL	S Atlantic Division medium
Milwaukee , WI	E S Central Division small
Minneapolis , MN	E S Central Division medium
New York , NY	W S Central Division small
Philadelphia , PA	W S Central Division medium
Phoenix , AZ	Mountain Division small
Pittsburgh , PA	Mountain Division medium
Portland , OR	Pacific Division small
Providence , RI	Pacific Division medium
Richmond , VA	Alaska
Riverside , CA	Hawaii
Sacramento , CA	

Notes: The cutoff between small and medium is defined by CBSA population of 193,000. This number corresponds to the first tercile of the observed city population distribution in the SIPP. Rural areas (i.e. areas not in any CBSA) are included with small CBSAs.

Figure A1: Map of cities in the model

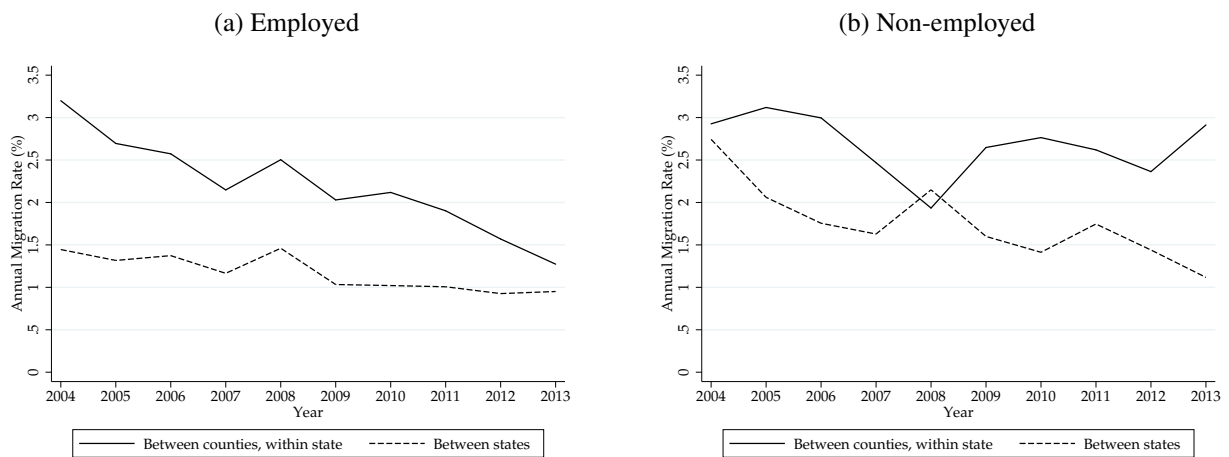


Note: Dots correspond to CBSA centroids of cities that are included in the model.

Table A5: Census divisions and their component states

Census Division Name	States Included
New England	CT, RI, MA, VT, NH, ME
Middle Atlantic	NY, NJ, PA
South Atlantic	DE, MD, DC, VA, WV, NC, SC, GA, FL
East South Central	KY, TN, MS, AL
East North Central	OH, IN, IL, WI, MI
West North Central	MN, IA, MO, KS, NE, SD, ND
West South Central	AR, LA, OK, TX
Mountain	MT, WY, CO, NM, AZ, UT, NV, ID
Pacific	CA, OR, WA, AK, HI

Figure A2: Annual migration rates by lagged employment status and migration distance for conventional definitions of employment and labor force participation



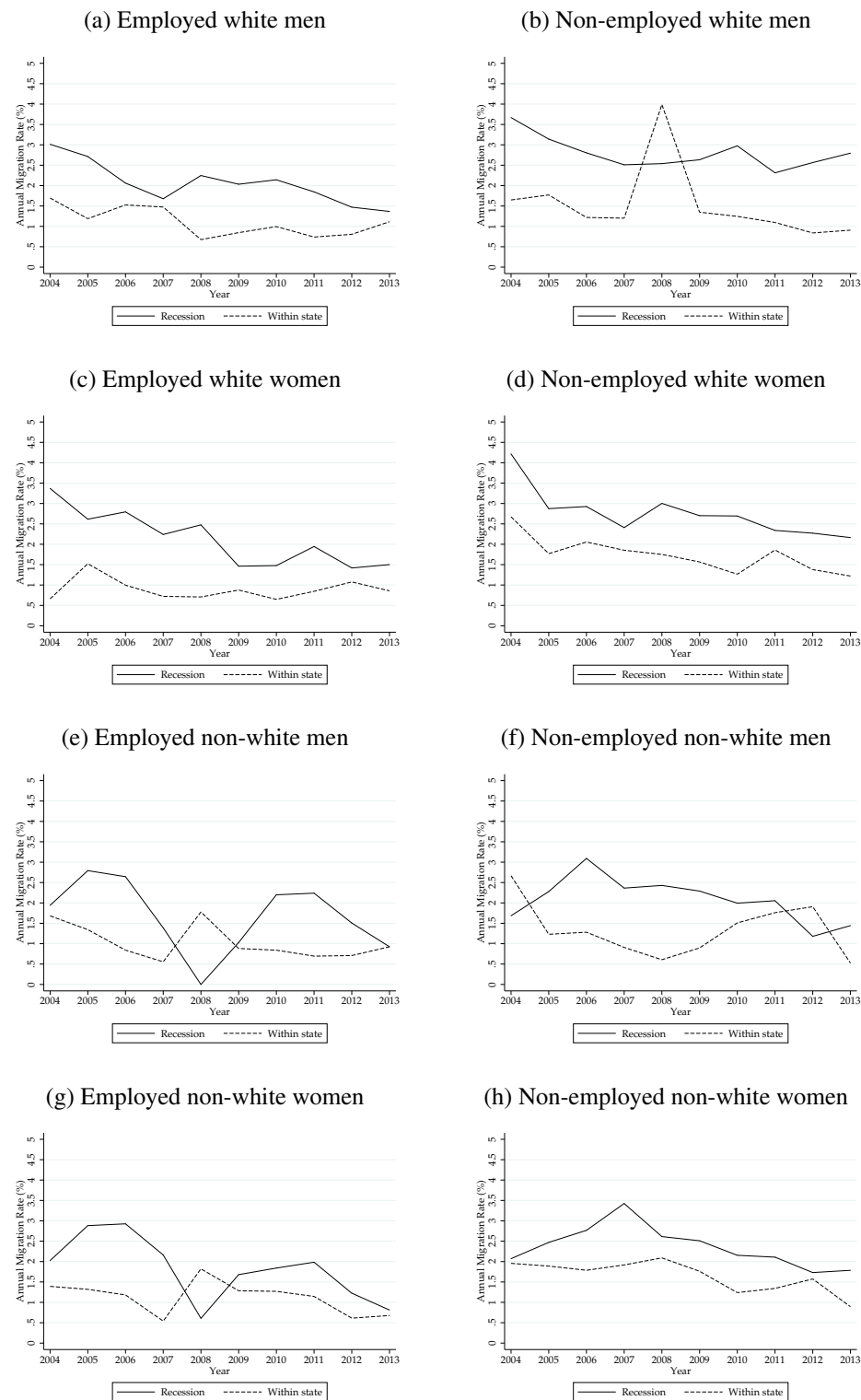
Source: 2004 and 2008 Panels of the Survey of Income and Program Participation. Figures include all non-college graduates aged 18-55 who have completed their schooling. Employment is defined as any amount of employment. Compare with Figure 1.

Table A6: Robustness of stylized facts to a more conventional definition of employment and labor force participation

Variable	Prev. employed		Prev. non-employed	
	Coeff	Std Err	Coeff	Std Err
Constant	0.8570***	0.0041	0.2337***	0.0084
Experience	0.0096***	0.0003	0.0060***	0.0006
Experience ² /100	-0.0168***	0.0007	-0.0113***	0.0016
Lagged state unempl. rate	-0.0044***	0.0004	-0.0049***	0.0009
Mover dummy	-0.1073***	0.0047	0.0948***	0.0083
Race \times gender dummies	✓		✓	
Observations	120,748		40,633	

Notes: Compare with Table 3, which uses a less conventional definition of labor force participation and employment. Results are estimates from a pair of linear probability models where the dependent variable is an indicator for being employed at all in the current period. Sample includes all non-college graduates aged 18-55 in the 2004 and 2008 panels of the public-use SIPP who have completed their schooling. *** p<0.01; ** p<0.05; * p<0.10.

Figure A3: Annual migration rates by lagged employment status and migration distance for various demographic sub-groups



Source: 2004 and 2008 Panels of the Survey of Income and Program Participation. Figures include all non-college graduates aged 18-55 who have completed their schooling. Employment is defined as full-time employment. Compare with Figure 1.

Table A7: Robustness of stylized facts to non-college-educated demographic sub-groups

Variable	Prev. employed		Prev. non-employed	
	Coeff	Std Err	Coeff	Std Err
<i>Panel A: Non-Hispanic White Men</i>				
Constant	0.7516***	0.0104	0.2331***	0.0115
Experience	0.0115***	0.0008	0.0081***	0.0009
Experience ² /100	-0.0193***	0.0017	-0.0190***	0.0022
Lagged state unempl. rate	-0.0057***	0.0009	-0.0075***	0.0013
Mover dummy	-0.0936***	0.0113	0.0799***	0.0157
Observations	37,237		23,112	
<i>Panel B: Non-Hispanic White Women</i>				
Constant	0.6820***	0.0131	0.1078***	0.0076
Experience	0.0117***	0.0010	0.0044***	0.0006
Experience ² /100	-0.0168***	0.0022	-0.0019	0.0017
Lagged state unempl. rate	-0.0026**	0.0011	-0.0047***	0.0009
Mover dummy	-0.1627***	0.0148	0.0356***	0.0103
Observations	26,249		33,239	
<i>Panel C: Non-White Men</i>				
Constant	0.6648***	0.0156	0.1592***	0.0127
Experience	0.0147***	0.0012	0.0119***	0.0010
Experience ² /100	-0.0264***	0.0029	-0.0278***	0.0030
Lagged state unempl. rate	0.0002	0.0015	-0.0056***	0.0016
Mover dummy	-0.088***	0.0213	0.0435**	0.0211
Observations	13,827		12,965	
<i>Panel D: Non-White Women</i>				
Constant	0.6845***	0.0159	0.1337***	0.0111
Experience	0.0132***	0.0013	0.0106***	0.0009
Experience ² /100	-0.0231***	0.0030	-0.0218***	0.0027
Lagged state unempl. rate	-0.0019	0.0015	-0.0046***	0.0014
Mover dummy	-0.1558***	0.0208	0.0281	0.0175
Observations	14,155		15,502	

Notes: Compare with Table 3, which pools all demographic groups in the SIPP. Results are estimates from pairs of linear probability models where the dependent variable is an indicator for being employed at all in the current period. Sample includes non-college graduates aged 18-55 in the 2004 and 2008 panels of the public-use SIPP who have completed their schooling. *** p<0.01; ** p<0.05; * p<0.10.

Table A8: Employment probability equation estimates, with and without controlling for marital status

Variable	No Control for Marital Status				Control for Marital Status			
	Prev. employed		Prev. non-employed		Prev. employed		Prev. non-employed	
	Coeff	Std Err	Coeff	Std Err	Coeff	Std Err	Coeff	Std Err
Constant	1.3056***	0.2220	0.2566	0.2237	1.2220***	0.2224	0.2361	0.2257
Experience	0.0858***	0.0091	0.0359***	0.0086	0.0715***	0.0093	0.0141	0.0088
Experience ² /100	-0.1228***	0.0208	-0.0285	0.0219	-0.0991***	0.0211	0.0070	0.0222
Lagged local unempl. rate	-0.0314***	0.0104	-0.0922***	0.0110	-0.0303***	0.0104	-0.0929***	0.0111
Mover dummy	-0.9257***	0.1280	0.1929	0.1557	-0.9325***	0.1282	0.2331	0.1569
Location fixed effects	✓		✓		✓		✓	
Marital status dummy					✓		✓	
Observations	30,898		9,949		30,898		9,949	
Persons	12,013		6,087		12,013		6,087	

Notes: Reported numbers are coefficients from logit regressions conditional on previous employment status. The first four columns coincide with results presented in Table 4. *** p<0.01; ** p<0.05; * p<0.10.

Table A9: Characteristics of destination location given moving cost subsidy to unemployed workers in various origin cities, year 2007

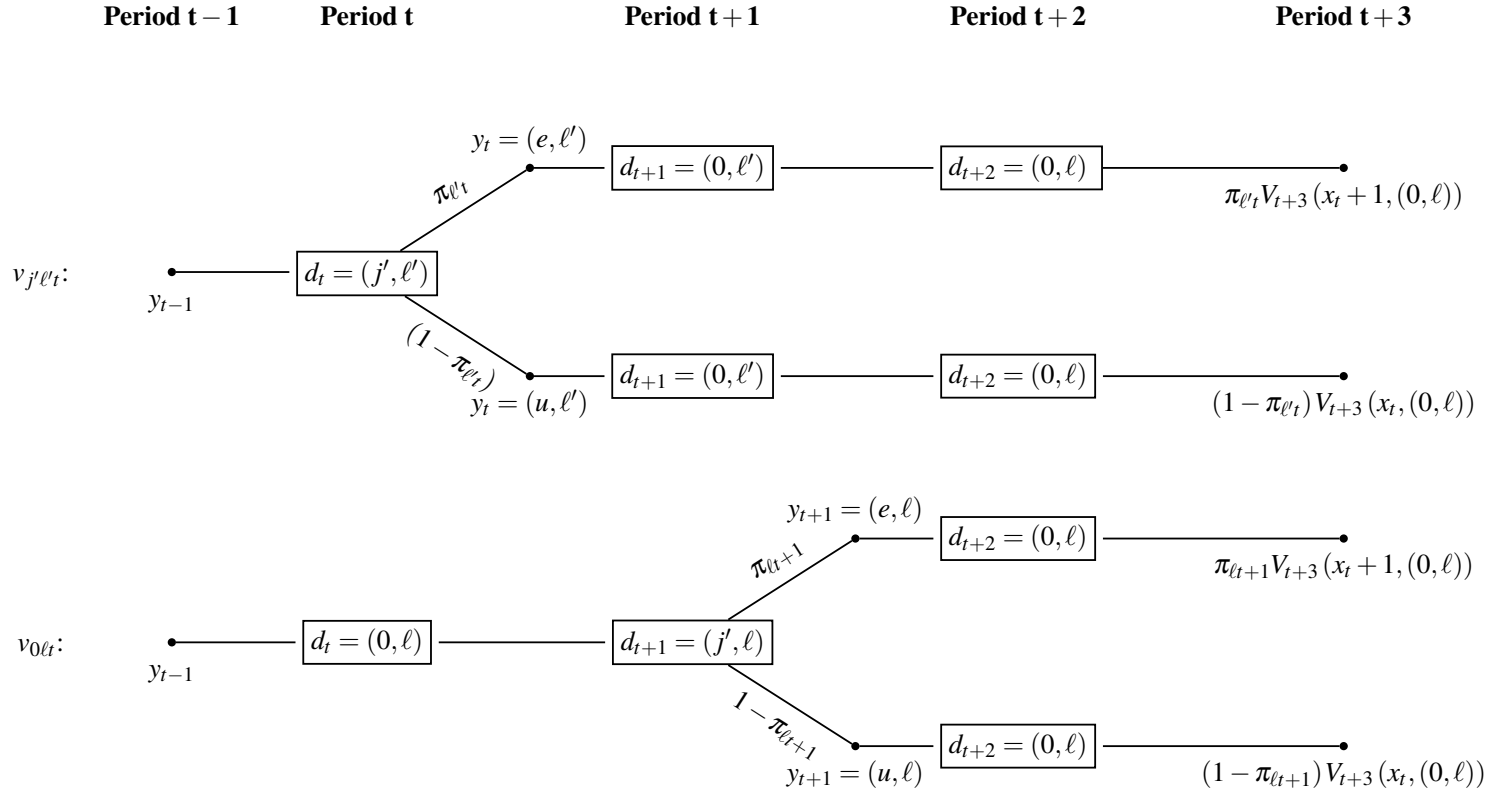
(a) Amenities								
	Type 1 workers				Type 2 workers			
	high amenity city		low amenity city		high amenity city		low amenity city	
	Coeff	Std Err	Coeff	Std Err	Coeff	Std Err	Coeff	Std Err
constant	0.3405	0.1790	0.4587	0.2750	0.3000	0.1643	0.4205	0.2643
amenities	0.0284*	0.0086	0.0436*	0.0132	0.0261*	0.0079	0.0419*	0.0127
earnings (conditional on working)	-0.0005	0.0067	-0.0008	0.0104	-0.0006	0.0062	-0.0009	0.0100
employment probability	0.0229*	0.0078	0.0352*	0.0120	0.0221*	0.0072	0.0357*	0.0116
ln(distance)	-0.0456*	0.0143	-0.0701*	0.0220	-0.0395*	0.0131	-0.0635*	0.0211
state of birth	0.2724*	0.0277	0.4195*	0.0426	0.2396*	0.0254	0.3859*	0.0410
region of birth	0.0149	0.0225	0.0230	0.0347	0.0129	0.0207	0.0208	0.0333

(b) Earnings level								
	Type 1 workers				Type 2 workers			
	high earnings city		low earnings city		high earnings city		low earnings city	
	Coeff	Std Err	Coeff	Std Err	Coeff	Std Err	Coeff	Std Err
constant	0.4162	0.2352	0.4151	0.2378	0.3745	0.2211	0.3749	0.2246
amenities	0.0372*	0.0112	0.0375*	0.0114	0.0349*	0.0106	0.0354*	0.0107
earnings (conditional on working)	-0.0007	0.0089	-0.0006	0.0090	-0.0008	0.0084	-0.0008	0.0085
employment probability	0.0298*	0.0103	0.0307*	0.0104	0.0296*	0.0097	0.0306*	0.0098
ln(distance)	-0.0603*	0.0188	-0.0603*	0.0190	-0.0535*	0.0176	-0.0537*	0.0179
state of birth	0.3611*	0.0364	0.3607*	0.0368	0.3255*	0.0343	0.3261*	0.0348
region of birth	0.0196	0.0296	0.0199	0.0300	0.0173	0.0279	0.0177	0.0283

(c) Employment probability level								
	Type 1 workers				Type 2 workers			
	high emp. prob. city		low emp. prob. city		high emp. prob. city		low emp. prob. city	
	Coeff	Std Err	Coeff	Std Err	Coeff	Std Err	Coeff	Std Err
constant	0.3823	0.2129	0.4558	0.2672	0.3304	0.1917	0.4290	0.2639
amenities	0.0337*	0.0102	0.0422*	0.0128	0.0303*	0.0092	0.0415*	0.0126
earnings (conditional on working)	-0.0006	0.0080	-0.0007	0.0101	-0.0007	0.0072	-0.0008	0.0100
employment probability	0.0263*	0.0093	0.0357*	0.0117	0.0251*	0.0084	0.0370*	0.0115
ln(distance)	-0.0553*	0.0170	-0.0666*	0.0213	-0.0471*	0.0153	-0.0618*	0.0211
state of birth	0.3313*	0.0330	0.3972*	0.0414	0.2868*	0.0297	0.3740*	0.0409
region of birth	0.0176	0.0268	0.0227	0.0337	0.0149	0.0242	0.0211	0.0333

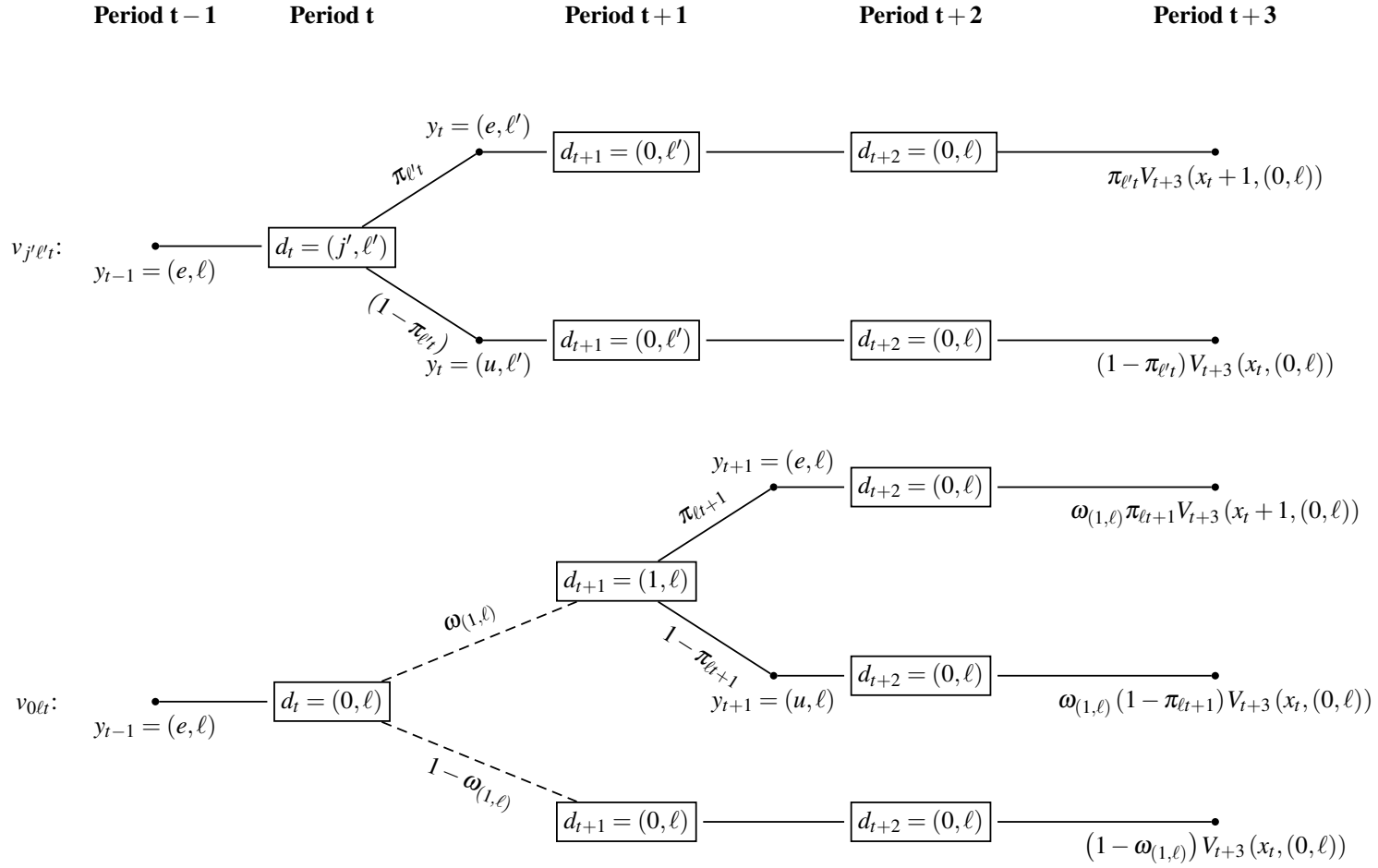
Notes: Dependent variable is predicted migration rate to location ℓ (in percentage points). Covariates are locational characteristics of the candidate destination locations. The amenities, earnings, and employment probability variables are each standardized to have mean-zero, unit variance. All locations (including synthetic locations) are included in the regression. Controls also included for local earnings drift, earnings volatility, unemployment drift, unemployment persistence, and unemployment volatility. * p<0.05

Figure A4: Finite dependence paths conditional on y_{t-1}



Note: This figure depicts the evolution of the state space given the finite dependence paths described in Section A.3.2. Cancellation of the future value terms does not occur unless $\pi_{\ell'_t} = \pi_{\ell_{t+1}}$. This equality does not hold in general.

Figure A5: Expanded finite dependence paths conditional on y_{t-1}



Note: This figure depicts the evolution of the state space given the finite dependence paths described in Section A.3.2. Cancellation of the future value terms occurs when $\omega_{(1,\ell)} = \frac{\pi_{\ell't}}{\pi_{\ell t+1}}$, as described in Equations (A.27) and (A.28).

Table A10: Estimates of unemployment rate forecasting equations

Parameter	Symbol	Mean	Std Dev
Drift	(ϕ_0)	0.0171	0.0052
Autocorrelation	(ϕ_1)	0.7670	0.0840
SD of shock	(σ_ξ)	0.0137	0.0035

Notes: Reported numbers are distributional moments of parameters from L separate AR(1) regressions.

Table A11: Earnings forecasting estimates

Parameter	Symbol	Mean	Std Dev
<i>Earnings</i>			
Drift	(ρ_0)	-0.0797	0.0352
Autocorrelation	(ρ_1)	0.7415	—
SD of shock	(σ_ζ)	0.0792	0.0416

Notes: Reported numbers are distributional moments of parameters from a pooled AR(1) regression with location-specific drift and shock variance, but common autocorrelation coefficient. The standard error of ρ_1 is 0.0359, which both rejects that the process is a unit root, and rejects that the process is white noise.

Table A12: Determinants of local labor market attributes

(a) Amenities, earnings, and employment levels

Variable	Amenities (α_ℓ)		Earnings (w_ℓ)		Job destruction (δ_ℓ)		Job offer (λ_ℓ)	
	Coeff	Std Err	Coeff	Std Err	Coeff	Std Err	Coeff	Std Err
constant	0.0422	0.3531	7.3423***	0.1919	0.5860***	0.0376	0.0019	0.1060
ln(population)	0.0023	0.0238	-0.0272**	0.0129	0.0150***	0.0025	0.0236***	0.0071
New England	-0.0017	0.0566	-0.1923***	0.0308	-0.0197***	0.0060	-0.0265	0.0170
Mid Atlantic	-0.0403	0.0553	-0.0057	0.0301	0.0239***	0.0059	-0.0123	0.0166
E N Central	-0.0572	0.0386	0.1036***	0.0210	0.0140***	0.0041	-0.0253***	0.0116
W N Central	0.0225	0.0531	0.1017***	0.0289	0.0442***	0.0057	-0.0525***	0.0159
S Atlantic	-0.0338	0.0398	0.0480**	0.0217	0.0268***	0.0042	0.0107	0.0120
E S Central	-0.0744	0.0659	0.1061***	0.0358	-0.0064	0.0070	0.1038***	0.0198
W S Central	-0.1033*	0.0551	0.2983***	0.0299	0.0591***	0.0059	0.0192	0.0165
Mountain	0.0274	0.0643	0.1071***	0.0350	-0.0046	0.0069	0.0771***	0.0193
R ²	0.3848		0.3368		0.4507		0.2230	

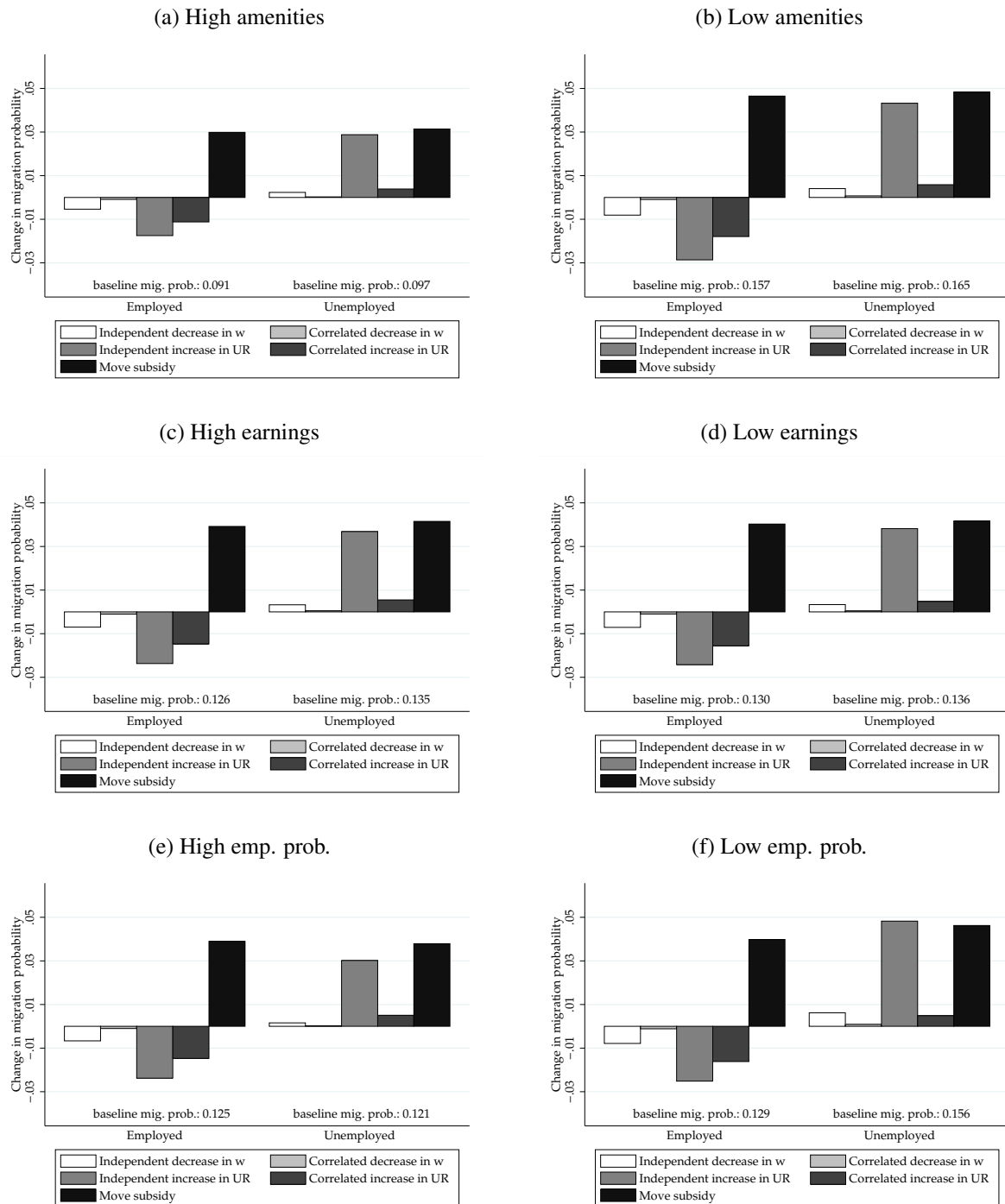
Notes: Each column is a separate regression with 350 observations (35 cities, 10 time periods) of the corresponding model parameter on the log population of the location and Census division dummies. Amenities and AR(1) shock standard deviations do not vary over time, so these regressions have 35 observations. *** p<0.01; ** p<0.05; * p<0.10

(b) Earnings and unemployment drift, persistence, and volatility

Variable	Earnings drift ($\rho_{0\ell}$)		UR drift ($\phi_{0\ell}$)		UR persistence ($\phi_{1\ell}$)		Earnings volatility (σ_{ξ_ℓ})		UR volatility (σ_{ξ_ℓ})	
	Coeff	Std Err	Coeff	Std Err	Coeff	Std Err	Coeff	Std Err	Coeff	Std Err
constant	-0.0630	0.1235	0.0190	0.0197	0.4310	0.2896	0.3938	0.3048	-0.0091	0.0137
ln(population)	-0.0018	0.0083	-0.0001	0.0013	0.0237	0.0195	-0.0192	0.0205	0.0018*	0.0009
New England	-0.0585***	0.0198	-0.0015	0.0032	-0.0132	0.0464	-0.0280	0.0489	-0.0034	0.0022
Mid Atlantic	-0.0113	0.0193	-0.0051*	0.0031	0.0505	0.0453	0.0172	0.0477	-0.0052***	0.0021
E N Central	0.0312***	0.0135	0.0028	0.0022	-0.0454	0.0317	-0.0188	0.0333	-0.0019	0.0015
W N Central	0.0136	0.0186	0.0011	0.0030	-0.0660	0.0436	-0.0123	0.0458	-0.0027	0.0021
S Atlantic	0.0008	0.0139	-0.0047**	0.0022	0.0394	0.0327	-0.0436	0.0344	-0.0024	0.0015
E S Central	0.0236	0.0231	-0.0002	0.0037	-0.0163	0.0541	-0.0284	0.0569	-0.0006	0.0026
W S Central	0.0672***	0.0193	0.0010	0.0031	-0.1074***	0.0452	-0.0787	0.0475	-0.0060***	0.0021
Mountain	0.0276	0.0225	-0.0026	0.0036	-0.0043	0.0527	-0.0393	0.0555	-0.0011	0.0025
R ²	0.5989		0.4347		0.5004		0.3534		0.3953	

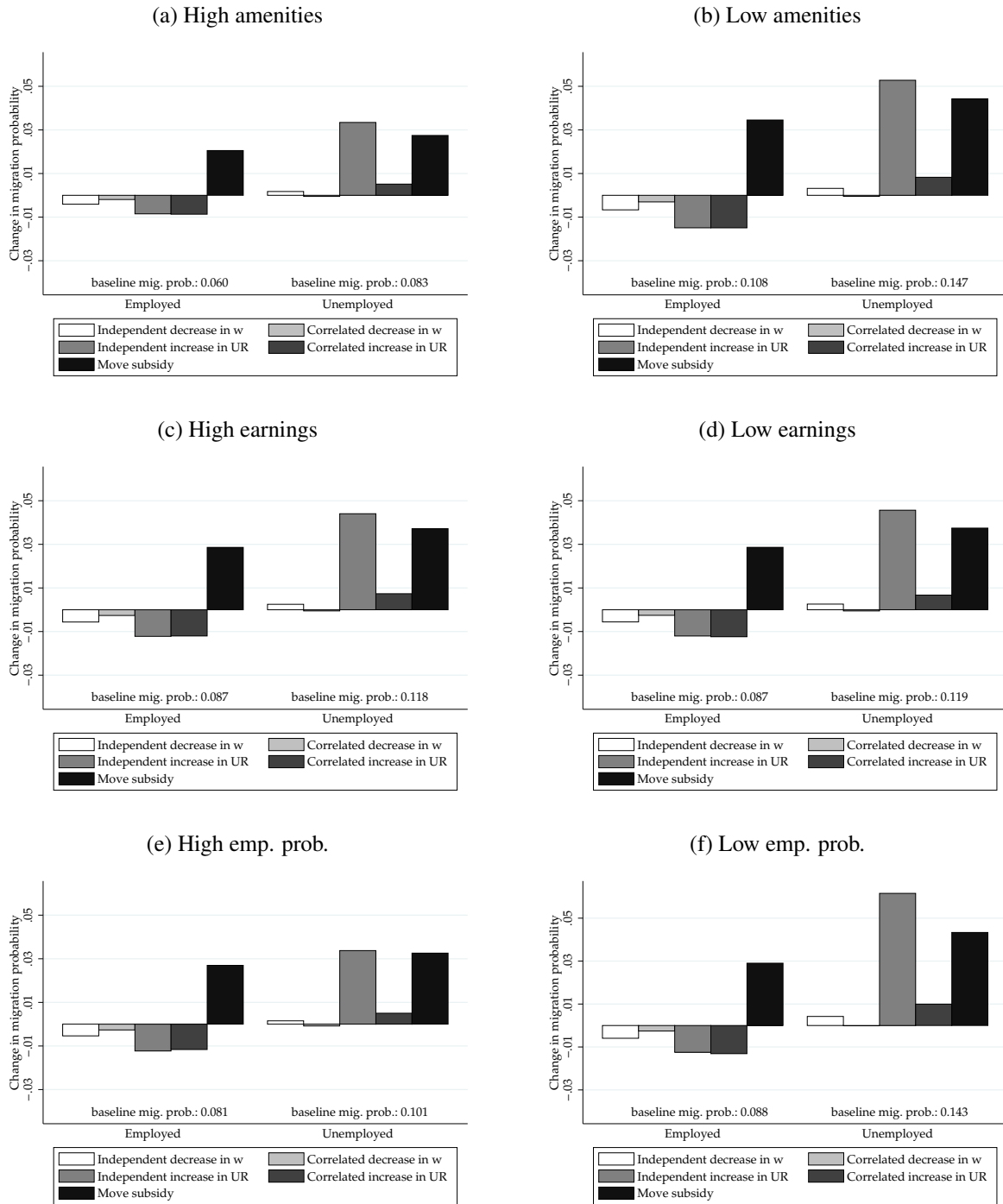
Notes: “UR” denotes unemployment rate. Each column is a separate regression with 350 observations (35 cities, 10 time periods) of the corresponding model parameter on the log population of the location and Census division dummies. Amenities and AR(1) shock standard deviations do not vary over time, so these regressions have 35 observations. *** p<0.01; ** p<0.05; * p<0.10

Figure A6: Counterfactual change in migration for Type 1 individuals, by origin city and prior employment status



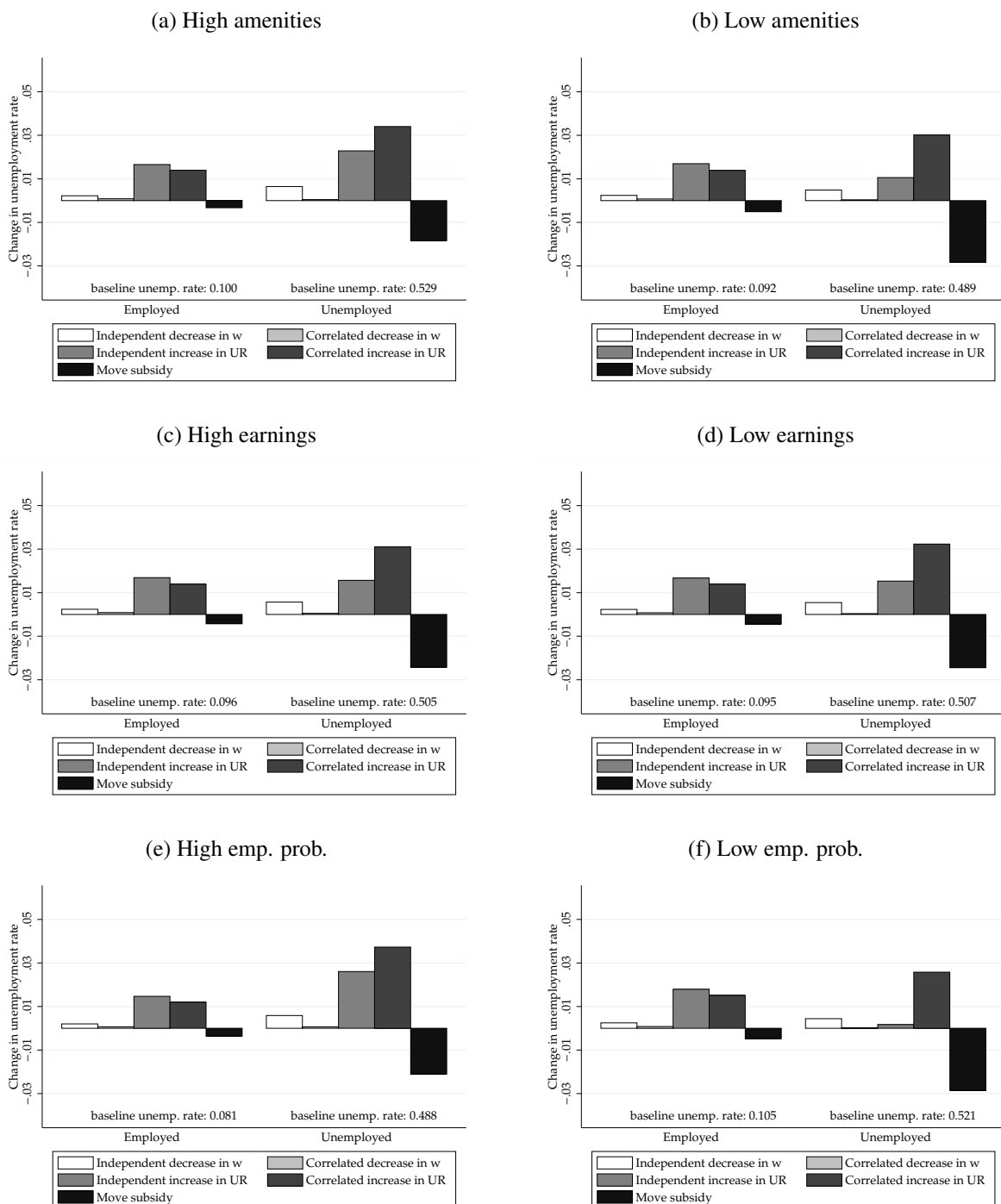
Notes: Each panel corresponds to a different origin city. Bar heights refer to the change in the out-migration rate from the specified location in response to the listed counterfactual. All figures are for 25-year-olds who were not born in the origin location. “high” refers to a location in the 75th percentile of the given distribution; “low” refers to the 25th percentile. All characteristics not set to “high” or “low” are set to the median. The earnings shock ($\downarrow w$) corresponds to the 70th percentile of the cross-location distribution in earnings AR(1) shock deviations. The unemployment shock corresponds to the jump from 2008 to 2009 for the average location in the data. To focus the results, each candidate location has median AR(1) parameters for both earnings and employment. Birth location is held fixed in all counterfactuals. Individual characteristics are set to the average for all 25-year-olds, conditional on employment status.

Figure A7: Counterfactual change in migration for Type 2 individuals, by origin city and prior employment status



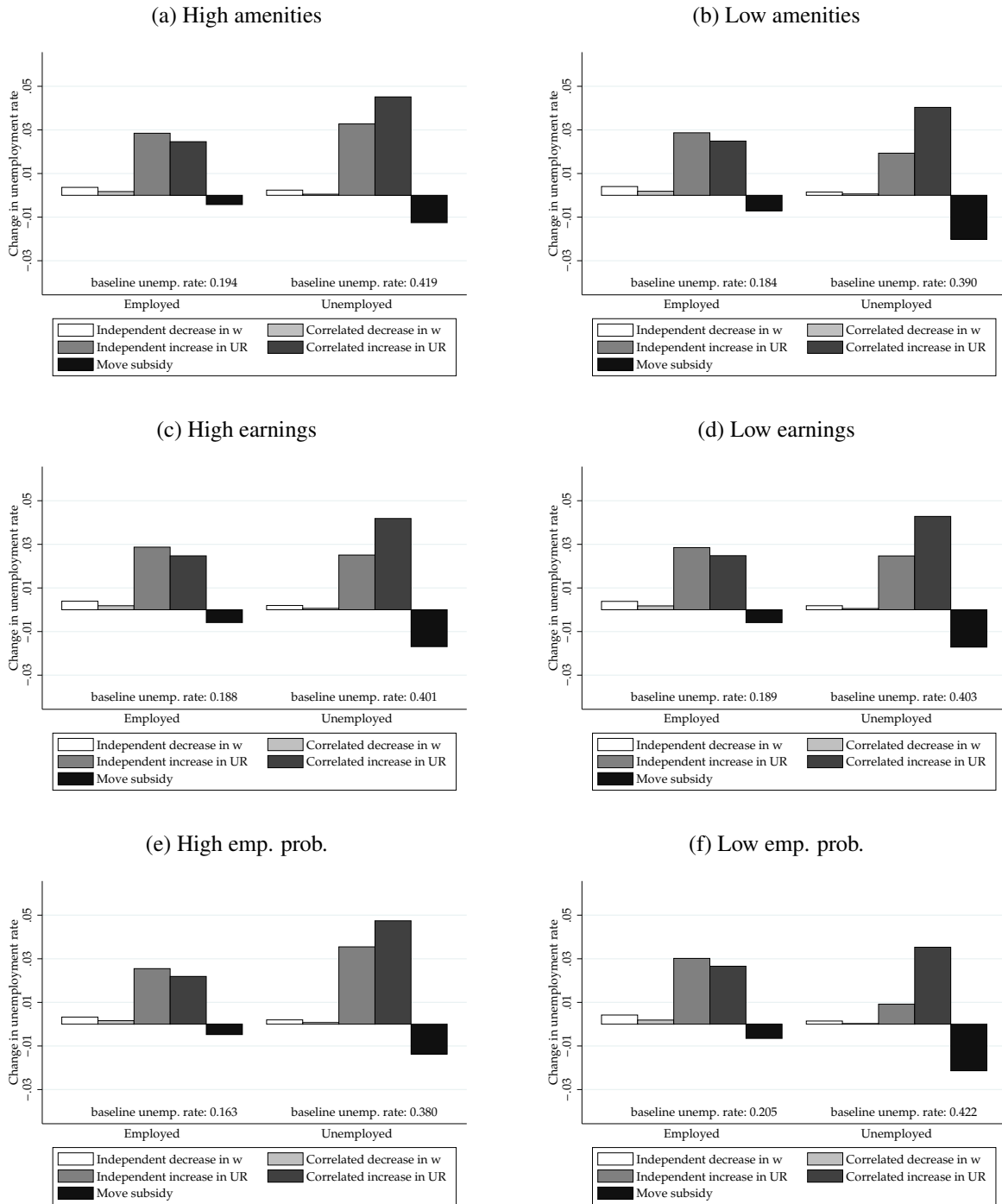
Notes: See notes to Figure 2.

Figure A8: Counterfactual change in unemployment rate for Type 1 individuals, by origin city and prior employment status



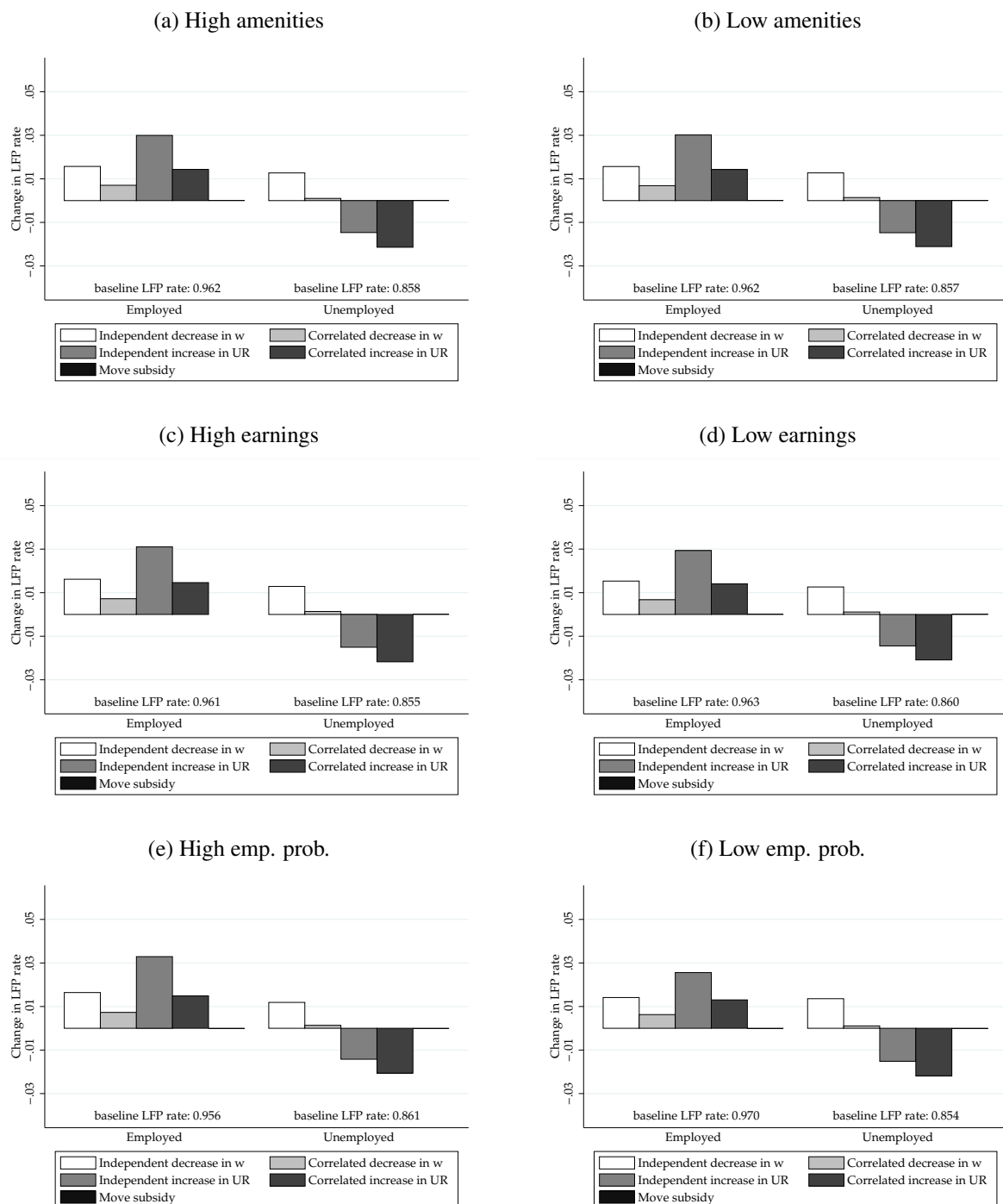
Notes: Each panel corresponds to a different origin city. Bar heights refer to the change in the out-migration rate from the specified location in response to the listed counterfactual. All figures are for 25-year-olds who were not born in the origin location. “high” refers to a location in the 75th percentile of the given distribution; “low” refers to the 25th percentile. All characteristics not set to “high” or “low” are set to the median. The earnings shock ($\downarrow w$) corresponds to the 70th percentile of the cross-location distribution in earnings AR(1) shock deviations. The unemployment shock corresponds to the jump from 2008 to 2009 for the average location in the data. To focus the results, each candidate location has median AR(1) parameters for both earnings and employment. Birth location is held fixed in all counterfactuals. Individual characteristics are set to the average for all 25-year-olds, conditional on employment status.

Figure A9: Counterfactual change in unemployment rate for Type 2 individuals, by origin city and prior employment status



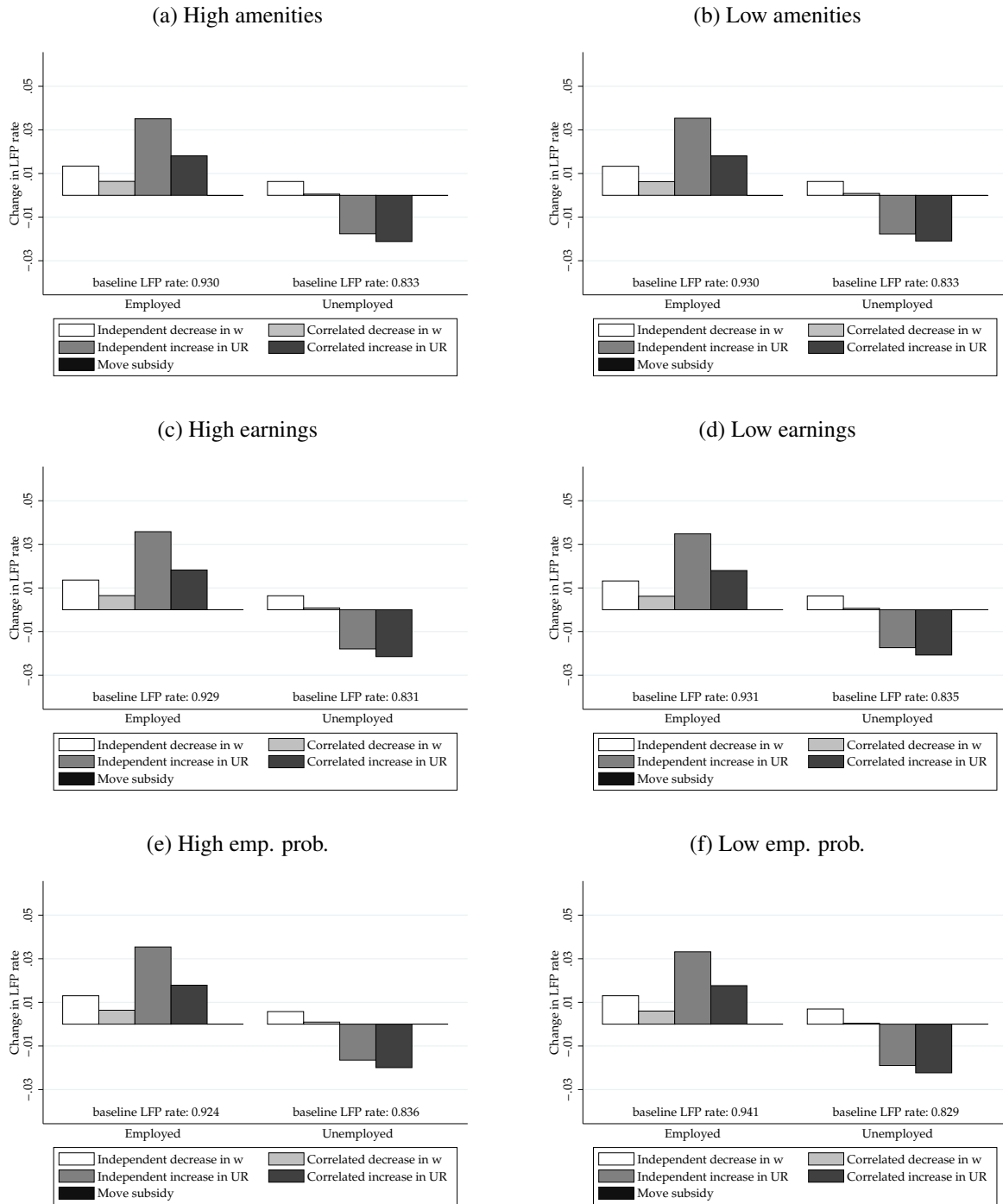
Notes: See notes to Figure 2.

Figure A10: Counterfactual change in labor force participation rate for Type 1 individuals, by origin city and prior employment status



Notes: Each panel corresponds to a different origin city. Bar heights refer to the change in the out-migration rate from the specified location in response to the listed counterfactual. All figures are for 25-year-olds who were not born in the origin location. “high” refers to a location in the 75th percentile of the given distribution; “low” refers to the 25th percentile. All characteristics not set to “high” or “low” are set to the median. The earnings shock ($\downarrow w$) corresponds to the 70th percentile of the cross-location distribution in earnings AR(1) shock deviations. The unemployment shock corresponds to the jump from 2008 to 2009 for the average location in the data. To focus the results, each candidate location has median AR(1) parameters for both earnings and employment. Birth location is held fixed in all counterfactuals. Individual characteristics are set to the average for all 25-year-olds, conditional on employment status.

Figure A11: Counterfactual change in labor force participation rate for Type 2 individuals, by origin city and prior employment status



Notes: See notes to Figure 2.

Table A13: Greek symbol notation glossary

Greek symbol	Equation of first reference	Description
α	(A.9)	Local amenities
β	(3.1)	Discount factor
γ	(A.9)	Flow utility parameters
$\bar{\gamma}$	(A.22)	Euler's constant
δ	(A.3)	Job destruction probability
ε	(A.6)	Preference shocks
ζ	(A.2)	Shocks to evolution of earnings parameters
η	(A.1)	Earnings measurement error
θ	(A.13)	Moving and switching cost parameters
λ	(A.3)	Job offer probability
μ	(A.15)	Parameters in estimation of employment probabilities
ξ	(A.4)	Shocks to evolution of unemployment rate
π	(A.7)	Employment probabilities
$\bar{\pi}$	(A.34)	Population unobserved type probabilities
ρ	(A.2)	Parameters governing evolution of earnings parameters
σ_{ζ}	(A.2)	Std deviation of shocks to evolution of earnings parameters
σ_{η}	(A.1)	Std deviation of earnings measurement error
σ_{ξ}	(A.4)	Std deviation of shocks to evolution of unemployment rate
ϕ	(A.4)	Parameters governing evolution of employment probabilities
ϕ^h	(A.38)	Density of wage equation errors
ψ	(A.1)	Earnings parameters
ω	(A.26)	Value function weights
τ	(A.1)	Unobserved type (discrete)
Δ	(A.9)	Moving cost
Λ	(A.36)	Likelihood contribution of employment probabilities
Θ	(A.15)	Employment probability determinants
Ξ	(A.9)	Switching cost
Ψ	(A.31)	Covariance of local labor market shocks