The Decline of the Rust Belt: A Dynamic Spatial Equilibrium Analysis

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Abstract

The purpose of this paper is to study the causes, welfare effects, and policy implications of the decline of the Rust Belt. I develop a dynamic spatial equilibrium model which consists of a multi-region, multi-sector economy comprised of overlapping generations of heterogeneous individuals. My estimates imply that goods-producing firms located in the Rust Belt had a 10 percent relative productivity advantage in 1960 compared to the rest of the U.S., which had fallen to -3 percent by the end of the sample period in 2010. As a consequence, a large fraction of the decline of the Rust Belt can be attributed to the reduction in its location-specific advantage in the goods-producing sector. The transition of the U.S. economy to a service sector economy is a less significant factor. The decline of the Rust Belt generated significant differences in welfare between individuals residing in the Rust Belt and those residing in other areas, particularly for the less educated. Policy experiments show that the inequality in welfare can be significantly reduced by subsidizing labor costs in the Rust Belt or reducing mobility costs.

Keywords: labor mobility, the Rust Belt, local labor market

1 Introduction

One of the most striking changes in the United States economy over the past 50 years has been the decline of industrial cities in the Midwest and parts of the Northeast, an area typically known as the Rust Belt.[1] The Rust Belt has experienced a relative decline in population, wages, and housing rents compared to other areas in the U.S. In 1960, 27 percent of the U.S. population lived in the Rust Belt. By 2010 the population of the Rust Belt had decreased to 19 percent. Similarly, in 1960, average wages and housing rents were higher in the Rust Belt than in other U.S. areas by 10 and 7 percent respectively. By 2010 the wage gap was eliminated and housing rents in the Rust Belt were 13 percent lower than elsewhere in the states. The purpose of this paper is to study the causes, welfare effects, and policy implications of this decline.

To understand the causes that led to the decline of the Rust Belt, I develop a new dynamic spatial general equilibrium model which accounts for changes in comparative advantages in the production of goods and services, changes in natural, location-specific advantages, and changes in the supply of skilled workers. There are two regions in the economy, the Rust Belt and the rest of the U.S. In each region, there are three production sectors: a goods-producing sector, a service sector, and a housing sector. Goods and services are produced using non-college-educated labor, college-educated labor, and capital. Changes over time in the overall productivity of these sectors in each region are affected by area-specific technological change, sector-biased aggregate shocks, and changes in magnitude of agglomeration externalities.

The model is comprised of overlapping generations of heterogeneous individuals

[1]The Rust Belt conventionally includes Illinois, Indiana, Michigan, Ohio, Pennsylvania, and Wisconsin.

who are born in one of the two regions. Individuals can move between regions, but face potentially significant mobility costs. Individuals are forward looking and choose among six discrete alternatives: the two location alternatives, each with three possible work alternatives (employed in the goods sector, employed in the service sector, and remaining out of the labor force). Individuals also decide on their consumption of housing services. In each period, individuals receive a wage offer from each region and sector, which depends on the region- and sector-specific skill rental price and the individual's accumulated sector-specific skill. In equilibrium, a region- and sector-specific skill rental price is determined by equating the skill price to its marginal revenue product, evaluated at the aggregate level of skill and capital in that region and sector. The level of an individual's skill depends on accumulated work experience in each sector and on the individual's level of education. Transitions between sectors also involve mobility costs which can differ across demographic groups. I use standard, finite-horizon dynamic programing techniques to model the dynamic behavior of individuals.

Housing services are produced using capital and land as inputs. Housing rental prices clear the market for housing services in each region at each point of time.

I define the dynamic, non-stationary equilibrium for this model. Since equilibria can only be computed numerically, I develop a new algorithm. Computing equilibria for this model is challenging for a number of reasons. First, I need to solve the dynamic programming problem of workers accounting for a rich set of state variables in a non-stationary environment. Second, I need to characterize equilibrium beliefs that workers hold over the evolution of key state variables. Computing full rational expectation equilibria is not feasible. Therefore, I adopt a forecasting rule that approximates the rational expectations equilibrium (Krusell and Smith, 1998). The equilibrium beliefs must be self-fullfiling. I adopt an iterative algorithm to determine the parameters of the beliefs process, extending the procedure developed in Lee and Wolpin (2006). Third, I need to impose market clearing conditions for a large number of markets. I show numerically that equilibria exist and can be computed with a high degree of accuracy.

To obtain a quantitative version of the model, I develop a strategy to estimate the parameters of the model using a simulated method of moments estimator. I use a variety of different data sources to construct moments used in the estimation. First, I have obtained data characterizing employment and wages from the U.S. Current Population Survey. Second, I use data on region- and sector-specific output and capital from the National Income and Product Accounts. Third, I obtained access to restricted-use data to calculate sector and regional transition from the National Longitudinal Survey of Youth 1979. Finally, I use data on migration status from the U.S. Census. I combine all these data sources and construct a large vector of moment conditions to identify and estimate the key parameters of the model.

Based on the estimated model, I assess the causes of the decline of the Rust Belt. Relative to a baseline in which there were no economy-wide changes since 1960, I find that 50 percent of the decline in the Rust Belt's share of output is due to the reduction in its location-specific advantage in the goods-producing sector. Relative to the same baseline, the transition of the U.S. economy to a service sector economy due to technological change explains 25 percent of the decline.[2] The third important factor that explains the decline of the Rust Belt is the growth of the share of college-educated people in the U.S. as a whole.

I then investigate the welfare effects of the decline of the Rust Belt. I find that the average welfare of individuals who resided in the Rust Belt at the age of 20 is

[2]See Coulson (1999) and Carlino, DeFina, and Sill (2001) for the discussion on the relative importance of national and local shocks with respect to regional employment growth.

2 to 4 percent lower than that of their counterparts in other areas. The regional difference in welfare for older individuals who are less mobile is significantly higher; the gap for them increased by up to 9.7 percent of lifetime welfare. It is also larger for less-educated individuals, who are estimated to have higher mobility costs.

Given these welfare differences, I consider the impact on the welfare gap of government place-based policies, such as wage or migration subsidies. I therefore conduct a variety of counterfactual policy experiments. Wage subsidy programs are a major part of the Empowerment Zone program that has been implemented in several distressed communities in the U.S. over the past 15 years. I find that a 20 percent wage subsidy for Rust Belt employment can eliminate the welfare gap between the two areas and increase employment and output in the economy as a whole.[3] I also find that migration subsidies significantly mitigate the welfare gap at a relatively small cost.

Some additional comments on the related literature. This paper is related to several strands of existing literature. The model extends an urban growth model (Eaton and Eckstein, 1997; Black and Henderson, 1999; Duranton, 2007; Rossi-Hansberg and Wright, 2007) to a setting with costly labor adjustment. I adopt mobility cost specifications of dynamic migration models (Bishop, 2012; Gemici, 2011; Kennan and Walker, 2011). My analysis also builds on Topel's (1986) dynamic general equilibrium of local labor markets to allow for sectoral choice and aggregate shocks, and extends (in a geographic dimension) the dynamic general equilibrium formulations of multi-sector economy by Lee and Wolpin (2006); Artuç, Chaudhuri, and McLaren (2010); and Dix-Carneiro (2013).

There are several explanations offered in the literature for the decline of the Rust

[3]Firms in the Empowerment Zone were eligible for a credit of up to 20 percent of the first $15,000 in wages earned in that year by each employee who lived and worked in the community.

Belt. First, technological change and economic globalization had a profound impact on regions oriented towards goods-production, especially on the Rust Belt (Feyrer, Sacerdote, and Stern, 2007).[4] Second, Glaeser and Ponzetto (2007) argue that the Rust Belt's location-specific advantage from easier access to waterways and railroads decreased over time. Average freight transportation costs fell more than 50 percent from 1960 to 2010 due to technological improvements and the deregulation of the transportation sector (Glaeser and Kohlhase, 2003).[5] Holmes (1998) finds decline in manufacturing activity when crossing a border from a right-to-work to a non right-to-work state. Alder, Lagakos, and Ohanian (2013) argue that limited competition in labor markets and output markets in the Rust Belt is responsible for the region's decline. Rappaport (2009) shows that rising per capita income can account for increasing migration toward areas with nice weather. I quantitatively assess the relative importance of several explanations which are potentially counteracting by placing them within a unified framework.

This paper is also related to a large literature in urban and labor economics that analyzes dynamic labor market adjustments and welfare effects of regional shifts in labor demand. Blanchard and Katz (1992) and Coen-Pirani (2010) find substantial population mobility in response to regional demand shocks. Topel (1986) and Bound and Holzer (2000) show that less-educated workers are less responsive to these demand changes, and thus suffer a larger welfare loss from these shocks.[6] There are three

[4]Employment in the goods-producing sector decreased from 42 percent to 22 percent of total employment from 1960 to 2010.

[5]Furthermore, water transportation became relatively obsolete; its costs increased and its share of total freight transportation decreased over the same period.

[6]There are various explanations for the lower mobility of less-educated individuals. Glaeser and Gyourko (2005) argue that declining housing rents disproportionately affect the less educated who spend a larger fraction of their income on housing consumption. Notowidigdo (2011) argues that increasing social transfers to declining areas explains in part the low mobility of the less educated.

key differences between those studies and my approach. First, I study the labor adjustment across sectors as well as across regions. Second, I consider the changes in housing rents as well as in wages. Finally, I explicitly model individuals' expectations about future values of these equilibrium objects.

My paper is also related to the international trade literature that studies local labor market outcomes affected by international trade shocks. Autor, Dorn, and Hanson (2012) and Kovak (2013) study local labor market outcomes from import competition in the U.S. and Brazil respectively. They find that greater exposure to import competition substantially decreases employment and wages in the local labor market. In contrast to these papers where labor is treated as either perfectly mobile or perfectly immobile, I allow for a costly labor adjustment.

This paper also contributes to the growing empirical literature on place-based policies.[7] The literature on state level Enterprise Zones finds mixed evidence on the effectiveness of these programs at generating jobs.[8] On the other hand, Busso, Gregory, and Kline (2013) find that the federal-level Empowerment Zone program was able to substantially increased employment and wages for local workers in the zone. They also find that the efficiency costs of the programs was relatively modest. I study the possible effects of alternative policies that were not implemented and calculate their potential welfare costs.

The rest of the paper is organized as follows. In the next section, I provide a brief descriptive history of the decline of the Rust Belt. The model is presented in Section 3, along with the solution algorithm. Section 4 introduces the estimation procedure and section 5 presents the estimation results. Section 6 provides a description and

[7]See Bartik (2002) and Glaeser and Gottlieb (2008) for reviews. See also Moretti (2011) for an overview of empirical studies on the place-based policies.

[8]See Busso, Gregory, and Kline (2013) and references therein.

analysis of the counterfactual experiments, and section 7 concludes.

2 A Brief History of the Decline of the Rust Belt

Table 1: The Rust Belt Shares of Output, Employment, Population, and Relative Wage

Period[a]	Output	Employment	Population	Relative Wage[b] Goods	Relative Wage[b] Services
1968–1974	0.27	0.27	0.26	1.16	1.04
1975–1979	0.25	0.25	0.25	1.17	1.03
1980–1984	0.23	0.23	0.23	1.18	1.02
1985–1989	0.22	0.22	0.22	1.13	0.98
1990–1994	0.21	0.22	0.22	1.09	0.97
1995–1999	0.21	0.21	0.21	1.12	1.01
2000–2004	0.20	0.21	0.20	1.09	1.00
2005–2010	0.18	0.19	0.19	1.06	0.97

Source: Bureau of Economic Analysis and U.S. March Current Population Survey (CPS)

[a.] Average of annual figures over the period.

[b.] Relative (Rust Belt-to-other U.S. areas) hourly wages.

The Rust Belt region has experienced a relative decline in output, employment, population, and wages as seen Table 1. Between 1968 and 2010, the Rust Belt's share of output decreased by 9 percentage points, from 27 to 18 percent; its share of employment decreased by 8 percentage points, from 27 percent to 19 percent; and its share of population decreased by 7 percentage points, from 26 percent to 19 percent.[9]

The region's relative drop in wages is most pronounced in the goods sector; the goods-sector wage gap between the Rust Belt and the rest of the U.S. decreased from 16 percent in 1968 to 6 percent in 2010. The wage gap in the service sector was smaller than that of goods sector: it decreased from 4 percent to -3 percent over the same period. Furthermore, the wage drop was not monotonic; there was a relatively rapid drop during 1975–1994 period. The mean housing rents were higher in the Rust Belt than in other areas by 7 percent in 1960, but 13 percent lower in 2010.

Table 2: Composition of Workforce and Population

	Share of Goods Sector		Share of Non-College-Educated	
Period[a]	Rust Belt	Other U.S.	Rust Belt	Other U.S.
1968–1974	0.46	0.38	0.79	0.74
1975–1979	0.42	0.34	0.73	0.67
1980–1984	0.39	0.32	0.68	0.62
1985–1989	0.35	0.30	0.64	0.58
1990–1994	0.33	0.27	0.57	0.52
1995–1999	0.31	0.26	0.50	0.47
2000–2004	0.30	0.24	0.46	0.43
2005–2010	0.27	0.23	0.44	0.41

Note: This table shows the share of goods-sector employment and non-college-educated population in each region. Sorce: U.S. March CPS

[a.] Average of annual figures over the period.

[9] All nominal figures were converted to 1983 dollars using the gross domestic product (GDP) deflator. The data on output come from National Income and Production Account (NIPA). Data on employment and wages are from March Current Population Survey (CPS).

The sector composition of the two regions differed substantially throughout the period, although similar changes occurred in both regions over time. Table 2 shows the share of goods sector employment in each region.[10] The share of goods sector employment was higher in the Rust Belt by 8 percentage points in 1968–1974 period. As the U.S. economy shifted from the goods sector to the service sector, the share of the goods sector decreased in both regions. However, the gap in sector composition between the two regions also decreased substantially. The share of the non-college-educated population decreased substantially over the period in both regions (Table 2). In 1964–1969 period, the share of the non-college-educated in the Rust Belt was 4 percentage points higher than that of elsewhere in the U.S., but that figure had increased to 6 percent in 1985–1989 period and then decreased to 3 percent by 2010.

Table 3 shows gross flows between regions separately by education level. Younger and college-educated individuals were more mobile than older and less-educated individuals. For example, 2.9 percent of college-educated individuals aged 25–34 in the Rust Belt moved to other areas per year, but that figure was only 0.7 percent for non-college-educated individuals aged 55–64. The regional mobility rate substantially decreased over time, especially for college-educated individuals.

[10]The goods sector consists of the mining, construction, and manufacturing industry categories; the service sector of the transportation and utilities, trade, finance, insurance, and other service industry categories.

Table 3: Annual Migration Rate

	From Rust Belt to Other Areas		From Other Areas to Rust Belt	
Age	Non-College	College	Non-College	College
25–34	1.5	2.9	0.4	0.6
35–44	1.0	1.4	0.3	0.3
45–54	0.7	1.0	0.2	0.2
55–64	0.7	1.0	0.2	0.1
Period[a]				
1982–1989	1.1	2.4	0.3	0.4
1990–1994	1.0	2.1	0.3	0.4
1995–1999	1.0	1.8	0.3	0.4
2000–2004	1.0	1.7	0.3	0.3
2005–2010	0.8	1.2	0.2	0.2

Note: This table shows the annual migration rate (%) by destination, education level, age, and period. Source: U.S. March CPS, 1982-2010

[a.] Average of annual figures over the period.

3 Model

3.1 Environment

Consider a small open economy with two regions. In each region, there are three production sectors: the goods-producing sector, the service sector, and the housing sector. I begin with the assumption that factor and product markets are competitive. However, these markets differ in their openness. Capital, goods, and service markets are open, thus the rental price of capital and goods and service prices are exogenous; that is, they are set internationally and taken as given. Labor and housing markets are not only closed but also regional, and thus their prices are competitively determined in each region.

The economy consists of overlapping generations of individuals aged 25–64. Individuals are initially (at age 25) heterogeneous in terms of their education level, $ed \in \{NC : \text{non-college}, C : \text{college}\}$, and the region where they grew up, $home \in \{1\text{: Rust Belt, 2: rest of U.S.}\}$. In addition, the population consists of two discrete unobservable types (Heckman and Singer, 1984; Keane and Wolpin, 1997) of individuals who permanently differ in skill endowments. An individual's type probability depends on the place he/she grew up and education level. Type probabilities are time-varying to the extent that the distribution of initial location and education level has changed.

Two regions are indexed by $i \in \{1 : \text{the Rust Belt}; 2 : \text{the remaining U.S.}\}$. Two production sectors are indexed by $j \in \{G : \text{goods}; S : \text{service}\}$.

3.1.1 Technology

The goods-producing sector and the service sector produce output Y using non-college-educated skill L^{NC}, college-educated skill L^{C}, and physical capital K. Each sector is also subject to an aggregate productivity shock z. Specifically, production of sector j located in region i at time t is given by:

$$\begin{aligned} Y_{ijt} &= z_{jt}A_{ijt}B_{ijt}F_j\left(L_{ijt}^{NC}, L_{ijt}^{C}, K_{ijt}\right) \\ &= z_{jt}A_{ijt}B_{ijt}\left[\alpha_{jt}^{1}\left(L_{ijt}^{NC}\right)^{\psi_j} + \alpha_{jt}^{2}\left(L_{ijt}^{C}\right)^{\psi_j} + \left(1-\alpha_{jt}^{1}-\alpha_{jt}^{2}\right)\left(K_{ijt}\right)^{\psi_j}\right]^{\frac{1}{\psi_j}} \end{aligned} \qquad (1)$$

where A_{ijt} is the agglomeration externality and B_{ijt} is location-specific advantage of the sector j in region i. The agglomeration externality (see Duranton and Puga, 2004; Rosenthal and Strange, 2004) depends on the aggregate skill density in the region:

$$A_{ijt} = \left[\frac{L_{iGt}^{NC}}{D_{it}}\right]^{\nu_1^j}\left[\frac{L_{iSt}^{NC}}{D_{it}}\right]^{\nu_2^j}\left[\frac{L_{iGt}^{C}}{D_{it}}\right]^{\nu_3^j}\left[\frac{L_{iSt}^{C}}{D_{it}}\right]^{\nu_4^j}$$

where D_{it} is the size of developed land in region i at time t.

Sector-specific real productivity, location-specific advantage, and factor shares changes are assumed to be time-varying. The sector-specific real productivity is subject to shocks, $\bar{z}_{jt} = p_{jt}z_{jt}$, that, evaluated at constant dollars (p_{jt} is the real price of sector j output), are assumed to follow a joint first-order vector auto-regressive process in growth rates:[11]

$$\log\bar{z}_{jt+1} - \log\bar{z}_{jt} = \phi_0^j + \sum_{k=G,S}\phi_k^j\left(\log\bar{z}_{kt} - \log\bar{z}_{kt-1}\right) + \epsilon_{jt+1} \qquad (2)$$

where the innovations are joint normal with the elements of the variance-covariance matrix σ_{jk}^{z}, $j,k = G,S$. The location-specific advantage B_{ijt} is assumed to be constant

[11] I do not distinguish between relative product price changes and sector-specific technological change.

up to 1960, then to follow piecewise linear trends with structural breaks at 1970, 1975, 1980, 1985, 1990, and 2000. The time-varying factor shares, reflecting factor-biased technological change, are assumed to be constant up to 1960 and then to follow different linear trends thereafter. Functional form specifications are in Appendix A.

In each region i, housing services H are produced using residential capital M and land D:[12]

$$H_{it} = \left[M_{it}\right]^{\kappa} \left[D_{it}\right]^{1-\kappa}$$

3.1.2 Choice Set

At each age, from $a = 25, ..., 64$, individuals choose among six discrete alternatives: two location alternatives $i \in \{1, 2\}$ with three work alternatives $j \in \{G : \text{goods}, S : \text{services}, O : \text{out of labor force}\}$ in each location. Let $\bar{d}_i^a$ denote an indicator variable which equals one if the individual chooses region i at age a and zero otherwise. Let $\underline{d}_j^a$ denote an indicator variable which equals one if the individual chooses sector j at age a and zero otherwise. Let d_{ij}^a denote an indicator variable which equals one if the individual chooses sector j located in region i at age a and zero otherwise. Since the alternatives are mutually exclusive, we have

$$\sum_{i=1,2} \bar{d}_i^a = 1$$

$$\sum_{j=G,S,O} \underline{d}_j^a = 1$$

$$\sum_{i,j} d_{ij}^a = 1$$

They also decide on their consumption level of numeraire and housing services: c^a and h^a.

[12] I ignore labor input for the housing services production function to simplify the analysis, since the share of labor input in the housing sector is less than 2%.

3.1.3 Preferences

The flow utility at each age a for an individual is given by

$$U^a = \sum_{ij} \gamma_{ij} d_{ij}^a + u\left(c^a, h^a\right) - \sum_{ii'} \delta_{ii'} \bar{d}_i^a \bar{d}_{i'}^{a-1} - \sum_{jj'} \omega_{jj'} \underline{d}_j^a \underline{d}_{j'}^{a-1}, \tag{3}$$

where γ is non-pecuniary benefits associated with choosing each region and sector, $u(\cdot;\cdot)$ is the separable consumption branch of the utility function, and δ and ω are the psychic costs of switching regions and sectors respectively.

I allow age-varying independent and identically distributed stochastic shocks for the non-pecuniary benefit from choosing alternative O (out of labor force). Preference shocks are joint normal with elements of the variance-covariance matrix given by σ_{ik}^O, $i, k = 1, 2$. Specifically,

$$\gamma_{iO} = \exp\left(\gamma_{iO}^0 + \gamma_O^1 \, \mathbb{1}\left(a > 60\right)\left(a - 60\right)\right) + \varepsilon_i^a.$$

The consumption branch of utility function has a Cobb-Douglas form.[13] Namely,

$$u\left(c^a, h^a\right) = \left[c^a\right]^{1-\mu} \left[h^a\right]^{\mu}.$$

I allow γ, δ and ω to be education-type specific parameters. Functional form specifications for δ and ω are in Appendix A.

3.1.4 Constraints

The individual faces the budget constraint

$$c^a + \sum_i p_{it} h^a \bar{d}_i^a = \sum_{i,j} w_{ijt}^a d_{ij}^a + y_t^{ed} \tag{4}$$

[13] I follow Davis and Ortalo-Magné (2011).

where w^a_{ijt} is the real wage (earnings) an individual of age a receives from working in region i and sector j at time t, p_{it} is the housing rental price, and y^{ed}_t is the education-type-specific non-labor income in period t.

An individual receives a wage offer in each period from each region and in each sector. I follow the Ben-Porath-Griliches specification of the wage function. Each sector-region-specific wage offer is the product of a sector-region-specific competitively determined skill rental prices (r) and the amount of sector-region-specific skill units possessed by the individual (θ). Skill units are produced through work experience (x) accumulated in each sector, and subject to idiosyncratic i.i.d. shocks. Specifically, an individual's (log) wage offer at age a and calendar time t in region i and sector j is

$$\begin{aligned}\log w_{ijt} &= \log r^{ed}_{ijt} + \log \theta_{ij} \qquad (5)\\ &= \log r^{ed}_{ijt} + \beta^{1,type}_j + \left(\sum_{k=G,S} \beta^2_{jk} x^a_k\right)^{\beta^3_j} - \beta^4_j \, \mathbb{1}(1 > 40)(a-40) + \epsilon^a_{ij}.\end{aligned}$$

Sector-specific work experience evolves as $x^a_j = x^{a-1}_j + d^{a-1}_j$, $j = G, S$. $\beta^{1,type}_j$ is the (sector-specific) skill endowment at age 25 for an individual with *type*, and the ϵ^a_{ij} is an age-varying shock to skill. Sector-specific work experience is a weighted sum of work experience across all sectors. Thus, in addition to the direct mobility cost associated with switching employment to a different sector, there is also a loss to the extent that accumulated work experience in the origin sector produces less composite work experience in the destination sector, that is, there is a loss of specific skill.

3.1.5 Capital and Land Ownership

There are remaining rentals paid to owners of capital and land in this economy. λ_t fraction of the total rental income is distributed to college-educated individuals, and the remaining portion to non-college-educated individuals. Within the two education groups, individuals own identical diversified portfolios of the domestic capital and land, and thus have equal shares of domestic capital and land.

3.1.6 Market Clearing

Each individual alive at time t maximizes the remaining expected discounted present value of their lifetime utility given their age, subject to (3)-(5), by choosing among the six alternatives. The maximized expected lifetime utility of an individual who is age a at time t is given by

$$V^a\left(\Omega_{at}\right) = \max_{\{d^a, c^a, h^a\}} \sum_{\tau=a}^{A} \mathbb{E}\left(\rho^{\tau-a} U^\tau \mid \Omega_{at}\right),$$

where ρ is the discount factor and Ω_{at} is the information set (or state space) at age a and time t. The information set consists of current idiosyncratic shocks, years of education and work experience, current and past skill rental prices, housing rental prices, non-labor income, and aggregate shocks, as well as other information used to forecast future prices.

At any time t, agents in the economy form a common forecast of the distribution of future skill rental prices, housing rental prices and non-labor income. Based on that forecast and each agent's current state, the alternative that is optimal is chosen. Aggregate skill supplied to each regional sector is the sum of the skill units of the individuals who choose that alternative. Let N_{at} be the total number of individuals who are aged a at time t. Aggregate skill supplies are given by

$$L_{ijt}^{NC} = \sum_{a=25}^{64} \sum_{n=1}^{N_{at}} \theta_{ij}^{nat} d_{ij}^{nat} \mathbb{1}\left(ed^{nat} = NC\right) \tag{6}$$

$$L_{ijt}^{C} = \sum_{a=25}^{64} \sum_{n=1}^{N_{at}} \theta_{ij}^{nat} d_{ij}^{nat} \mathbb{1}\left(ed^{nat} = C\right)$$

The aggregate supply of capital is perfectly elastic at the current rental price of capital, and aggregate demand is equal to the sum of demand in the four regional sectors. Given the static nature of the labor demand side of the model, aggregate skill demand is determined by equating the marginal revenue product of aggregate skill for each region and sector to its current (equilibrium) skill rental price. The amount of capital used in each sector at time t is given by equating the marginal revenue product of the capital to the exogenous rental price of the capital, r_t^K. Specifically,

$$\begin{aligned} \frac{\partial p_{jt} Y_{ijt}}{\partial L_{ijt}^{NC}} &= r_{ijt}^{NC} \\ \frac{\partial p_{jt} Y_{ijt}}{\partial L_{ijt}^{C}} &= r_{ijt}^{C} \\ \frac{\partial p_{jt} Y_{ijt}}{\partial K_{ijt}} &= r_t^K \end{aligned} \tag{7}$$

The aggregate housing demand in region i is the sum of the housing consumptions of the individuals who choose the region i:

$$H_{it} = \sum_{a=25}^{64} \sum_{n=1}^{N_{at}} h^{nat} \bar{d}_i^{nat}$$

Given the exogenous supply of developed land, the aggregate housing supply in region i is given by equating the marginal revenue product of the capital to the exogenous rental price of the residential capital, r_t^M, so that

$$H_{it} = \left[\frac{\kappa p_{it}}{r_t^M} \right]^{\frac{\kappa}{1-\kappa}} D_{it} \tag{8}$$

At each time t, the housing demand and supply in each region should be equal.

The education-type-specific non-labor income in each period is given by

$$y_t^{ed} = \frac{\lambda_t^{ed}}{N_t^{ed}} \left[\sum_{ij} r_t^K K_{ijt} + \sum_i p_{it} H_{it} \right] \tag{9}$$

where N_t^{ed} is the total number of individuals with education level ed in this economy.

Let v_t denote a vector that contains the following equilibrium aggregate variables: equilibrium skill rental prices, housing rental prices, and non-labor income.

$$v_t = \left\{ r^{NC}_{1Gt}, r^{NC}_{1St}, r^{NC}_{2Gt}, r^{NC}_{2St}, r^{C}_{1Gt}, r^{C}_{1St}, r^{C}_{2Gt}, r^{C}_{2St}, p_{1t}, p_{2t}, y^{NC}_t, y^{C}_t \right\}$$

I assume that the solution to (7)-(9) for the growth rate of v_t can be approximated by the function:[14]

$$\begin{aligned} \log v_{it+1} - \log v_{it} &= \eta_i^0 + \sum_{k=1}^{12} \eta_i^k \left(\log v_{kt} - \log v_{kt-1} \right) \\ &+ \eta_i^{13} \left(\log z_{Gt+1} - \log z_{Gt} \right) + \eta_i^{14} \left(\log z_{St+1} - \log z_{St} \right). \end{aligned} \quad (10)$$

3.2 Solution of Model

The solution of model requires data for several exogenous varialbles: size of developed land, distribution of initial location and education level of entering cohort, cohort size, and capital rental price. Apendix B contains details of data inputs. The solution algorithm is an extension of the method developed in Lee and Wolpin (2006). See Apendix C for details.

[14] There can be an approximation error because the environment is non-stationary. For example, I allow for the growth rates of population and land supply to be non-constant. Therefore, rational expectation would imply that the aggregate state variable process given by (10) is also time-varying. Furthermore, I am agnostic as to what individuals know about future technological changes (for example, β_{ijt} and α_{jt}) or about the future value of other exogenous variables, such as relative product prices, the rental price of capital.

4 Estimation Method

The model parameters are estimated by simulated method of moments (SMM).[15] Specifically, the SMM estimator minimizes a weighted distance measure between sample aggregated statistics and their simulated analogs. The weights are given by the inverse of estimated variances of the sample statistics.[16]

The simulated aggregate statistics are generated for any given set of parameters and the derived series of equilibrium prices and aggregate shock by simulating the behavior of samples of 800 individuals per cohort, starting from cohorts that turned age 25 in 1929 (and thus would be age 64 in 1968), and ending with cohorts that turned age 25 in 2010. Therefore, cross-sectional simulated moments contain 32,000 observations. Simulated moments weight each cohort by their representation in the population of 25 to 64-year-olds.

The data come from the several sources. The March Current Population Surveys over the period 1968–2011 and the (restricted-use) National Longitudinal Surveys 1979 youth cohort over the period 1979–1993 provide information on life cycle employment, location and schooling choices, and wages; various U.S. Censuses from

[15]Some parameters are determined prior to SMM procedure. Housing share of consumption μ is estimated as the ratio between aggregate housing expenditure and personal income in NIPA. I do not estimate the factor share in housing production function. It is instead fixed at 0.65. See Davis and Palumbo (2008) for the related discussion.

[16]The model parameters are identified by a combination of functional form and distributional assumptions, along with exclusion restrictions. Identification of the wage offer parameters follows from standard selection correction arguments. Utility function parameters are identified because of the existence of variables in the wage function that do not enter the utility function; for example, sector-specific work experience. Identification of production function parameters follows from the existence of valid instruments for input level. Fore example, current and past cohort sizes and renal prices of capital are assumed to be exogenous, and thus are valid instruments.

1960 to 2010 provide data on migration status; and National Income and Production Account (NIPA) provides data on sectoral capital stocks and outputs.[17]

The CPS data spans cohorts from 1904 and to 1985 during some period of their lifetimes between the ages of 25 and 64. CPS data can be used to compute the choice and wage distributions for those cohorts and ages. However, it does not have a history of employment choices that would enable the calculation of work experience because it is primarily a cross-sectional data set. The NLSY79 is a longitudinal data set that surveys cohorts born from 1957 to 1964 annually from 1979 to 1994 and on a biennial basis from 1996 to the present. I use the NLSY79 data to calculate aggregate statistics that represent, or are conditioned on, sector-specific work experience.

The decision period is assumed to be annual in the estimation of the model. To accommodate the fact that individuals do not necessarily engage in the same activity over an entire calendar year, the choice variables are defined as follows: an individual is assigned to the work alternative if he or she worked at least 39 weeks and at least 20 hours per week during the calendar year. When the individual is assigned to the work category, his or her sector and location is that of the job held during the year (CPS) or the most recent job (NLSY79). The hourly wage is based on the same job assignment.

The following is a list of aggregate statistics that are employed in estimation:

- Career decisions

[17] I follow the adjustment procedure that is suggested by Lee and Wolpin (2006) when I combine CPS data on wages and BEA data on capital and output. Without this adjustment, the estimates for factor shares can be biased for the following reasons: First, national income (NI) and GDP differ by the level of business taxes. I deflate the skill rental price for each sector-region by the ratio of NI to GDP. Second, wages do not reflect total labor compensation. I augment CPS wages with BEA data on non-wage benefits in carrying out the estimation.

1. The proportion of individuals choosing each of the six alternatives by year (1968–2010) and age (25–64).
2. The proportion of individuals choosing each of the six alternatives by year and education level (non-college-educated; college-educated).
3. The proportion of individuals choosing each of the six alternatives by year and past choice.
4. The proportion of individuals choosing each of the six alternatives at age 25 by year and location at age 20.
5. The proportion of individuals choosing each of the six alternatives by experience and education level.
6. The proportion of individuals choosing each of the six alternatives by location at age 20 and education level.

- Wages

1. The mean of the log hourly real wage by region- and sector-categories, education levels, and year.
2. The variance of the log hourly real wage by region- and sector-categories, education levels, and year.[18]
3. The mean one-year difference in the log hourly real wage by current and one-year lagged sector by education level.
4. The mean log hourly real wage by work experience and education level.
5. The mean log hourly real wage by location at age 20 and education level.

- Mean non-labor income by year and education levels.

[18] I also allow for log-normally distributed measurement error in the reported hourly wage rate.

- Career transitions

  1. One-period joint transitions between two location alternatives by year (1982–2010) and education level.
  2. One-period joint location transitions by age and education level.
  3. One-period joint transitions between two sectors by year.[19]
  4. One-period joint sectoral and home transitions by age and education level (matched CPS).
  5. five-period joint transitions between two location alternatives by decade (1970–2010) and education level.
  6. distribution of years of work experience in each sector.

- Location- and sector-specific capital and output by year.

5 Results

5.1 Parameter Estimates

The parameter estimates and their standard errors[20] are shown in Table 18–Table 20 in Appendix D. I normalize some parameters because skill is not observable, but must

[19] A number of years are missing because identifiers that match households between consecutive years are not available. The missing transitions are between 1971 and 1972, 1972 and 1973, 1976 and 1977, 1985 and 1986, and 1995 and 1996.

[20] Let G be the matrix of derivative of the moments with respect to the model parameters, and S be the variance-covariance matrix of the moments. The variance-covariance matrix of the parameter estimates is given by $(G'WG)^{-1}G'WSWG(G'WG)^{-1}$ where weighting matrix W is given by the inverse of a diagonal matrix that contains variances of the moments.

be inferred from wages. Thus, the constant terms in the skill production functions cannot be separately identified from the level of skill rental prices. I normalize the constant term in each sector skill production function for a type 1 person to zero. As a result, the levels of skill rental prices across sectors are not comparable, although their changes over time are identified. The non-pecuniary benefits associated with employment in the goods sector of the Rust Belt are also normalized to zero. Therefore, the non-pecuniary benefits of working in the service sector and consumption values of leisure are relative to this normalization.

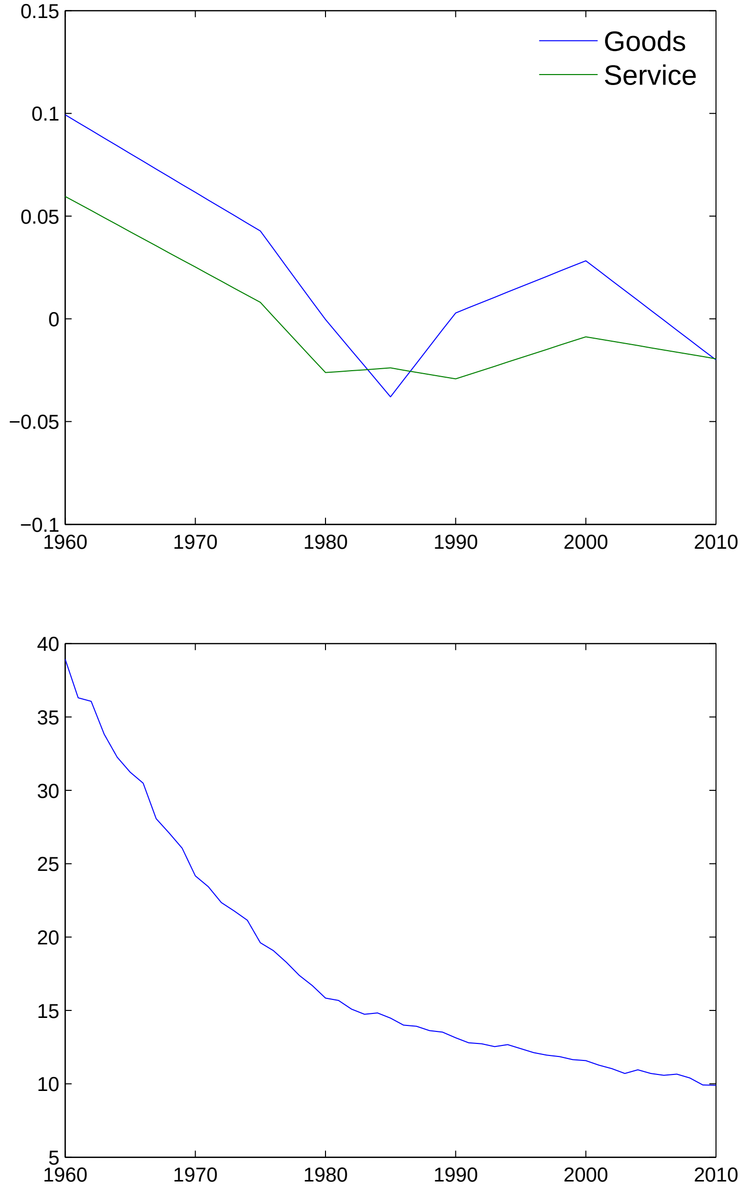
The parameters are categorized in the tables as they appear in the model section according to their equation number. I discuss those that are of particular interest.

5.1.1 Production Function Parameters

Figure 1 provides evidence of the significant reduction of the Rust Belt's location-specific advantage and the relative decline of goods sector real productivity from 1960 to 2010. The Rust Belt region was 10 percent more productive in producing goods than other areas in 1960; however, the advantage had fallen to -3 percent in 2010. In the service sector, the Rust Belt had a small location-specific advantage in 1960, but had become less productive than other areas in 2010. The combination of product price changes and Hicks-neutral technological change led to a relative decline in the real productivity of the goods sector.

The magnitude of agglomeration externality is small. It explains only one percentage point drop in the relative productivity of the goods sector in the Rust Belt. For the service sector, the agglomeration externality did not play any role.

Figure 1: Location-Specific Advantage and Sector-Specific Real Productivity



Note: The figures show the (upper figure) the Rust Belt's location-specific advantage $\left(\frac{B_{1jt}}{B_{2jt}}\right)$ and relative goods-to-services real productivity $\left(\frac{z_{Gt}}{z_{St}}\right)$.

5.1.2 Utility Parameters

Mobility costs are presented in Table 21. The cost of moving between regions within the same sector is estimated to be significantly larger than moving between sectors within the same region. For example, for a non-college-educated person aged 26, the cost of moving between regions ranges from $64,151 to $65,907, but for the same person, the cost of changing sectors within a region ranges only from $8,180 to $32,835. When changing regions within a sector, however, the cost is higher for less-educated individuals. For example, within a sector, the mobility cost of moving from the Rust Belt to the rest of the U.S. are $64,151 and $59,278 for non-college-educated and college-educated individuals aged 26 respectively. Lastly, the cost of moving between regions is significantly larger for order individuals. For example, for a non-college-educated person aged 26, the cost of moving between regions ranges from $64,151 to $65,907 , but when aged 64, the cost of changing sectors within a region ranges from $93,807 to $177,016.

5.1.3 Skill Production Functions

Table 22 shows the estimates for skill production function parameters. Experience obtained in a given sector is not perfectly transferable to other sectors. For example, in the case of skills gained by non-college-educated individuals in the goods sector, the weight on experience gained in the goods sector is 0.0093, and the weight on experience obtained in the service sector is 0.0001. However, in the case of goods sector college-educated skill, the weight on experience gained in the goods sector is 0.0680, but the weight on experience obtained in the service sector is 0.0065.

Table 4: Actual and Predicted Rust Belt Shares of Output, Employment, and Population

Period[a]	Output		Employment		Population	
	Actual	Predicted	Actual	Predicted	Actual	Predicted
1968–1974	0.27	0.26	0.27	0.26	0.26	0.26
1975–1979	0.25	0.25	0.25	0.24	0.25	0.25
1980–1984	0.23	0.24	0.23	0.24	0.23	0.24
1985–1989	0.22	0.22	0.22	0.22	0.22	0.24
1990–1994	0.21	0.21	0.22	0.22	0.22	0.23
1995–1999	0.21	0.20	0.21	0.21	0.21	0.22
2000–2004	0.20	0.19	0.21	0.20	0.20	0.21
2005–2010	0.18	0.19	0.19	0.19	0.19	0.20

[a.] Average of annual figures over the period.

5.2 Model Fit

Table 4–Table 9 present evidence on how well the model fits the data. Table 4 compares the Rust Belt shares of output, employment, and population over time in the actual data to that from the estimated model. The fit for the Rust Belt shares of output, employment, and population are very close, capturing their decrease over time. Table 5 shows the relative (Rust Belt-to-other U.S. areas) hourly wage by sector. The fit for the relative hourly wages is also close, although it is slightly underestimated for the service sector.

Table 5: Actual and Predicted Relative Hourly Wage by Sector

	Goods Sector		Service Sector	
Period[a]	Actual	Predicted	Actual	Predicted
1968–1974	1.16	1.16	1.04	1.00
1975–1979	1.17	1.16	1.03	0.99
1980–1984	1.18	1.13	1.02	0.97
1985–1989	1.13	1.09	0.98	0.96
1990–1994	1.09	1.11	0.97	0.95
1995–1999	1.12	1.10	1.01	0.96
2000–2004	1.09	1.08	1.00	0.95
2005–2010	1.06	1.08	0.97	0.95

Note: This table compares the relative (Rust Belt-to-other U.S. areas) hourly wage in the actual data to that from the estimated model.

a. Average of annual figures over the period.

Table 6: Actual and Predicted Goods-Sector Share of Employment by Region

Period	Rust Belt		Other U.S. Areas	
	Actual	Predicted	Actual	Predicted
1968–1974	0.46	0.43	0.38	0.36
1975–1979	0.42	0.42	0.34	0.34
1980–1984	0.39	0.38	0.32	0.32
1985–1989	0.35	0.33	0.30	0.29
1990–1994	0.33	0.32	0.27	0.26
1995–1999	0.31	0.30	0.26	0.24
2000–2004	0.30	0.27	0.24	0.23
2005–2010	0.27	0.25	0.23	0.22

[a.] Average of annual figures over the period.

The fit of the model with respect to the composition of the workforce and population in each region is also close. Table 6 shows that the model captures both the Rust Belt's higher specialization in the goods sector and the declining goods-sector share of employment in both areas. As in Table 7, the proportion of non-college educated individuals in each region is also matched very well.

Table 7: Actual and Predicted Share of Non-College-Educated Population by Region

Period	Rust Belt		Other U.S. Areas	
	Actual	Predicted	Actual	Predicted
1968–1974	0.79	0.78	0.74	0.75
1975–1979	0.73	0.72	0.67	0.67
1980–1984	0.68	0.67	0.62	0.62
1985–1989	0.64	0.63	0.58	0.58
1990–1994	0.57	0.57	0.52	0.52
1995–1999	0.5	0.51	0.47	0.46
2000–2004	0.46	0.47	0.43	0.43
2005–2010	0.44	0.45	0.42	0.41

[a.] Average of annual figures over the period.

The fit of the model with respect to the extent of state dependence in the choice of region, in particular, one-period transition rates, is also matched quite well. Table 8 shows that the model can fit the fact that young and college-educated individuals are more mobile than older and less-educated individuals. As in Table 9, the estimated model also captures the declining trend in mobility rates over time.

Table 8: Actual and Predicted Annual Migration Rate by Education Level and Age

	Age[a]	Non-College-Educated		College-Educated	
		Actual	Predicted	Actual	Predicted
From Rust Belt to Other U.S. Areas	25–34	1.5	1.3	2.9	2.1
	35–44	1.0	0.7	1.4	1.4
	45–54	0.7	0.5	1.0	1.0
	55–64	0.7	0.5	1.0	1.0
From Other U.S. Areas to Rust Belt	25–34	0.4	0.3	0.6	0.4
	35–44	0.3	0.2	0.3	0.3
	45–54	0.2	0.2	0.2	0.3
	55–64	0.2	0.2	0.1	0.3

Note: This table compares annual migration rate by education level and age in the actual data to that from the estimated model.

[a.] Average of annual figures over the age group.

Table 9: Actual and Predicted Migration Rate by Education Level and Period

		Non-College-Educated		College-Educated	
	Period[a]	Actual	Predicted	Actual	Predicted
From Rust Belt to Other U.S. Areas	1982–1989	1.1	1.0	2.4	1.9
	1990–1994	1.0	1.0	2.1	1.8
	1995–1999	1.0	0.9	1.8	1.5
	2000–2004	1.0	0.8	1.7	1.3
	2005–2010	0.8	0.8	1.2	1.0
From Other U.S. Areas to Rust Belt	1982–1989	0.3	0.4	0.4	0.6
	1990–1994	0.3	0.3	0.4	0.5
	1995–1999	0.3	0.2	0.4	0.4
	2000–2004	0.3	0.3	0.3	0.3
	2005–2010	0.2	0.3	0.2	0.3

Note: This table compares annual migration rate by education level and period in the actual data to that from the estimated model.

[a.] Average of annual figures over the period.

6 Discussion

6.1 The Decline of the Rust Belt

There are four major exogenous factors in the model that can account for the relative decline of the Rust Belt: (1) the reduction in the Rust Belt's location-specific advantage in the goods sector; (2) the reduction in the Rust Belt's location-specific advantage in the service sector; (3) the relative decline of the goods sector real productivity in the U.S. economy; and (4) the relative decline of the non-college-educated population in the U.S. economy. The first three factors are labor demand side explanations for the decline of the Rust Belt. The fourth factor is a labor supply side change.

To isolate the importance of each factor, I perform the following thought experiment. Suppose the world had stopped changing after 1960 in terms of the four factors mentioned above. When compared with that world, how would the U.S. economy have evolved under alternative scenarios in which some of these factors changed as they did in actuality and others did not, and would those new worlds diverge from what actually happened?

I consider six counterfactual scenarios. Experiment 1 allows for the reduction of the Rust Belt's location-specific advantage in the goods sector. Experiment 2 allows for the reduction of the Rust Belt's location-specific advantage in the service sector. Experiment 3 allows for the real productivity of both sectors to evolve as actually occurred. Experiment 4 allows for the share of the non-college-educated population in the U.S. to evolve as it actually did. Experiment 5 simultaneously implements factors in experiments 1, 2, and 3. And finally, Experiment 6 simultaneously implements factors in experiments 1, 2, 3, and 4.[21]

Table 10 shows the effects of these four factors on the Rust Belt's share of output, employment, and population. I find that each of the four factors accounts for a substantial part of the relative decline of the Rust Belt. With respect to the decline of the Rust Belt's share of output and employment, demand side factors are important. The results for Experiments 1 and 2 show that about 50 (29) percent of the decline in the Rust Belt's share of output can be attributed solely to the reduction in the Rust Belt's location-specific advantages in the goods (service) sector. The result for Experiment 3 shows that the declining real productivity of the goods sector in U.S. economy explains about 25 percent of the decline.

Table 11 shows the effects of these four factors on population and the relative (the Rust Belt-to-other areas) wages. The labor supply side factor was important for the reduction in the Rust Belt's share of the population. My estimate implies that non-college-educated individuals get higher utility from living in the Rust Belt than the college-educated do. Thus the reduction in the share of the non-college-educated population generates the relative decline of the Rust Belt population. Experiment 4 shows that the drop in the share of the non-college-educated population in the overall U.S. population can account for 45 percent of decline in the Rust Belt's overall share of population. As expected, the labor supply side factor (Experiment 4) cannot account for any part of the relative decline of wages in the Rust Belt. On the other hand, the combined effect of labor demand side factors (Experiment 5) led to a decrease in the relative wages more than actually occurred.

[21]For each simulation, I assume that the distribution of entering cohort's (age 25) initial location at age 20 in period t is assumed to be the same as the distribution of the location choice of 50-year-old individuals in period $t-5$. This assumption is based on the actual pattern in Census. The share of individuals in the Rust Belt at age 20 is close to that of ages 45–50.

Table 10: The Effect of Sectoral and Regional Technological Changes on Rust Belt Shares of Output and Employment

			Counterfactual Experiment					
	Period[a]	Base	1	2	3	4	5	6
Output	1968–1974	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	1975–1979	0.96	0.99	1.00	1.01	1.00	0.97	0.96
	1980–1984	0.92	0.96	1.00	1.00	1.02	0.93	0.92
	1985–1989	0.87	0.94	0.98	0.99	1.01	0.88	0.87
	1990–1994	0.84	0.94	0.96	0.98	1.00	0.85	0.84
	1995–1999	0.81	0.94	0.96	0.97	1.00	0.83	0.81
	2000–2004	0.77	0.93	0.96	0.96	0.99	0.81	0.78
	2005–2010	0.76	0.89	0.93	0.94	0.95	0.78	0.76
Employment	1968–1974	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	1975–1979	0.97	0.99	0.99	1.00	0.99	0.98	0.96
	1980–1984	0.96	0.99	1.01	1.01	1.00	0.97	0.96
	1985–1989	0.92	0.97	0.98	1.00	0.99	0.94	0.91
	1990–1994	0.89	0.97	0.97	1.00	0.99	0.92	0.90
	1995–1999	0.85	0.96	0.96	0.98	0.97	0.90	0.86
	2000–2004	0.82	0.96	0.96	0.97	0.96	0.89	0.84
	2005–2010	0.81	0.93	0.93	0.96	0.93	0.85	0.81

[a.] Average of annual figures over the period.

Table 11: The Effect of Sectoral and Regional Technological Changes on Population and Relative Wages

			Counterfactual Experiment					
	Period[a]	Base	1	2	3	4	5	6
Population	1968–1974	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	1975–1979	0.98	1.00	1.00	1.00	0.99	0.99	0.98
	1980–1984	0.96	0.99	1.00	1.00	0.98	0.98	0.96
	1985–1989	0.94	0.99	1.00	1.00	0.98	0.97	0.94
	1990–1994	0.91	0.98	0.99	1.00	0.97	0.96	0.93
	1995–1999	0.88	0.98	0.98	0.99	0.95	0.95	0.90
	2000–2004	0.85	0.96	0.97	0.98	0.94	0.93	0.88
	2005–2010	0.83	0.95	0.96	0.97	0.92	0.91	0.86
Wages	1968–1974	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	1975–1979	0.99	1.00	1.01	1.02	1.02	0.99	0.99
	1980–1984	0.94	0.96	0.99	0.99	1.02	0.95	0.95
	1985–1989	0.93	0.96	0.99	1.00	1.02	0.92	0.93
	1990–1994	0.92	0.96	0.98	0.99	1.02	0.90	0.92
	1995–1999	0.92	0.96	0.99	0.99	1.04	0.90	0.91
	2000–2004	0.91	0.95	1.00	0.99	1.04	0.90	0.90
	2005–2010	0.91	0.94	0.99	0.97	1.03	0.89	0.90

Note: This table shows the effect of sectoral and regional technological changes on population and the relative (Rust Belt-to-other U.S. areas) hourly wages. The baseline column shows the result in the estimated model.

[a.] Average of annual figures over the period.

6.2 Welfare Analysis

In this section, I compute the difference in welfare between individuals in the two regions in two scenarios: (1) the difference in welfare between individuals who reside in the Rust Belt at age 20 and those who reside in other areas at age 20; and (2) the welfare differences for individuals at ages 45–64 with at least 10 years of experience in the goods sector. The differences are presented in terms of the present value of the welfare, which are computed over the actual transition path. The welfare differences are computed for different cohorts and demographic groups.

Table 12: The Difference in Welfare across Regions

	(1)		(2)	
Period[a]	Non-College	College	Non-College	College
1968–1974	-2.0	-2.0	4.3	5.2
1975–1979	-2.7	-1.8	3.0	2.8
1980–1984	-2.8	-1.9	1.3	-0.6
1985–1989	-3.0	-2.1	2.6	-1.9
1990–1994	-3.1	-2.2	-0.2	-0.7
1995–1999	-3.8	-2.2	-7.6	-2.4
2000–2004	-4.0	-2.3	-9.7	-5.8
2005–2010	-2.7	-2.5	-5.9	-7.1

Note: This table shows the regional welfare inequality in terms of lifetime welfare (%). (1) The difference in welfare between the individuals residing in the Rust Belt and those residing in other U.S. areas at age 20. (2) The welfare differences for the individuals at ages 45–64 with at least 10 years of experience in the goods sector.

[a.] Average of annual figures over the period.

The first two columns in Table 12 show that the welfare losses of the individuals in the Rust Belt were larger for the non-college-educated population and increased over time. However, the magnitude of the welfare loss was not large in spite of the fact that the relative wage of the Rust Belt decreased by more than 10 percentage points over time. This can be explained by the fact that individuals are relatively mobile between ages 20 and 25; on average about 8% (22%) of non-college-educated (college-educated) individuals moved out of the Rust Belt between ages 20 and 25. The last two columns in Table 12 show that the welfare losses are large for individuals who are older and have long experiences in goods sector. As expected, the welfare is higher for individuals in the Rust Belt before 1980 because the older individuals' remaining lifetime welfare is mostly determined by the higher goods sector (real) wage in the Rust Belt (Table 13). However, between 2000–2004, the welfare of individuals in the Rust Belt is lower by 9.7% and 5.8% for non-college-educated and college-educated individuals respectively.

6.3 The Effects of Place-Based Policies

In this section, I describe the results of simulation experiments designed to examine how government place-based policies (such as wage or moving subsidies) for the Rust Belt can influence the dynamic adjustment process, welfare inequality across regions, and total welfare of the economy.[22] To satisfy the budget balance need, the costs of policies are equally distributed to all the individuals in the economy in the form of a lump-sum tax.[23]

[22]Total welfare of the economy is sum of all the individual utilities in the economy. As I mention in Section 3, individuals are owners of labor, domestic capital, and land; therefore, their utilities capture the welfare of capitalists and landlords as well as workers.

[23]More precisely, each individual's non-labor income decreases to pay the lump-sum tax. Additionally, the subsidy programs are unexpected events to individuals prior to 1960.

Table 13: Relative (Housing Rental Price Adjusted) Skill Rental Prices

Period[a]	Non-College		College	
	Goods	Service	Goods	Service
1968–1974	1.13	0.96	1.18	1.03
1975–1979	1.09	0.94	1.13	1.03
1980–1984	1.06	0.93	1.11	1.00
1985–1989	1.07	0.91	1.10	0.97
1990–1994	1.08	0.92	1.09	0.95
1995–1999	1.06	0.93	1.08	0.95
2000–2004	1.05	0.93	1.06	0.95
2005–2010	1.04	0.95	1.04	0.94

Note: This table shows the relative (Rust Belt-to-other U.S. areas) housing price adjusted skill rental prices by sector.

[a.] Average of annual figures over the period.

First, I consider 10% and 20% wage subsidies for the Rust Belt. The wage subsidy program is a major part of the Empowerment Zone program that was implemented in several distressed communities in the U.S. from 1994 to 2009. Firms in the Empowerment Zone were eligible for a credit of up to 20% of the first $15,000 in wages earned in that year by each employee who lived and worked in the community (Busso, Gregory, and Kline, 2013).

I also consider a moving subsidy as an alternative policy to mitigate the welfare gap between the regions. Specifically, I subsidize 100% of mobility costs of non-college-educated (college-educated) 25-year-old individuals who resided in the Rust Belt at the age 20. The subsidies amount to $37,617 ($21,101) for non-college-educated (college-educated) individuals.

Table 14 shows the subsidies' impacts on the Rust Belt's shares of output, employment, and population, as well as on the relative wages. The 10% wage subsidy program reduces the drop in the Rust Belt's shares of output, employment, and population by approximately 50 percent. However, its impact on the relative wage is modest. The 20% wage subsidy program enables the Rust Belt to actually increase its shares of output, employment, and population. In addition, the 20% subsidy substantially reduces the fall in the relative wage in the Rust Belt. The moving subsidy, however, exacerbates the decline of the Rust Belt; with it in place, the region's share of output, employment, and population decrease further compared to the baseline case.

Table 16 compares the subsidies' impacts on welfare inequality across regions. The difference in welfare between the individuals residing in the Rust Belt and those residing in other areas at age 20 can be reduced about 60%, compared to the baseline case, by enacting a 10% subsidy. The welfare of the individuals residing in the Rust Belt actually becomes higher than its counterpart in other areas under the 20% wage

Table 14: The Effects of Subsidies on Rust Belt Shares of Output, Employment, Population, and Relative Wage

	Period[a]	Base	10% Wage	20% Wage	Moving
Output	1968–1974	1.00	1.00	1.00	1.00
	1975–1979	0.96	0.98	1.02	0.95
	1980–1984	0.92	0.94	1.00	0.89
	1985–1989	0.87	0.91	1.00	0.84
	1990–1994	0.84	0.89	1.00	0.79
	1995–1999	0.81	0.87	1.00	0.76
	2000–2004	0.77	0.86	0.99	0.73
	2005–2010	0.76	0.86	1.01	0.72
Employment	1968–1974	1.00	1.00	1.00	1.00
	1975–1979	0.97	0.98	1.01	0.96
	1980–1984	0.96	0.97	1.01	0.93
	1985–1989	0.92	0.94	1.01	0.88
	1990–1994	0.89	0.93	1.02	0.85
	1995–1999	0.85	0.91	1.02	0.82
	2000–2004	0.82	0.90	1.02	0.79
	2005–2010	0.81	0.90	1.04	0.77

Note: This table shows the effect of subsidies on Rust Belt shares of output, employment, population, and relative wage.

[a.] Average of annual figures over the period.

Table 15: The Effects of Subsidies on Rust Belt Shares of Output, Employment, Population, and Relative Wage

	Period[a]	Base	10% Wage	20% Wage	Moving
Population	1968–1974	1.00	1.00	1.00	1.00
	1975–1979	0.98	0.99	1.02	0.96
	1980–1984	0.96	0.98	1.02	0.94
	1985–1989	0.94	0.97	1.03	0.91
	1990–1994	0.91	0.96	1.05	0.88
	1995–1999	0.88	0.94	1.06	0.85
	2000–2004	0.85	0.93	1.06	0.82
	2005–2010	0.83	0.93	1.08	0.80
Wage	1968–1974	1.00	1.00	1.00	1.00
	1975–1979	0.99	1.00	1.01	0.98
	1980–1984	0.94	0.96	0.99	0.93
	1985–1989	0.93	0.95	0.98	0.92
	1990–1994	0.92	0.93	0.96	0.91
	1995–1999	0.92	0.93	0.96	0.91
	2000–2004	0.91	0.92	0.96	0.90
	2005–2010	0.91	0.92	0.96	0.90

Note: This table shows the effect of subsidies on Rust Belt shares of output, employment, population, and relative wage.

[a]. Average of annual figures over the period.

Table 16: The Effects of Subsidies on the Regional Difference in Welfare

	Period[a]	Base	10% Wage	20% Wage	Moving
Non-College	1968–1974	-1.9	-0.4	2.3	-0.5
	1975–1979	-2.7	-1.2	1.0	-1.1
	1980–1984	-2.8	-1.6	1.0	-1.5
	1985–1989	-3.0	-1.0	1.0	-1.5
	1990–1994	-3.1	-0.7	2.5	-1.5
	1995–1999	-3.8	-0.7	1.3	-2.2
	2000–2004	-4.0	-1.3	1.2	-2.5
	2005–2010	-2.7	-1.0	0.7	-1.4
College	1968–1974	-2.0	-1.1	0.7	-0.5
	1975–1979	-1.8	-1.2	0.4	-0.5
	1980–1984	-1.9	-1.3	0.3	-0.6
	1985–1989	-2.1	-1.0	0.8	-0.8
	1990–1994	-2.2	-1.4	0.1	-0.9
	1995–1999	-2.2	-1.0	0.9	-1.1
	2000–2004	-2.3	-0.9	0.5	-1.0
	2005–2010	-2.5	-1.0	0.9	-1.2

Note: This table shows the effect of subsidies on the difference in welfare between individuals residing in the Rust Belt and those residing in the other U.S. areas.

[a.] Average of annual figures over the period.

Table 17: The Effects of Subsidies on Employment Rate, Output, and Welfare

		10%	20%	Moving
Employment Rate	Total	3.3%	8.5%	0.2%
	Rust Belt	7.1%	15.9%	-0.5%
	Other U.S. Areas	2.1%	5.6%	0.3%
Output	Total	7.1%	18.1%	0.3%
	Goods	24.6%	86.2%	-0.8%
	Service	1.5%	-3.5%	0.7%
Cost	Welfare Loss/Total Welfare	-0.39%	-1.72%	-0.03%
	Welfare Loss/Subsidy Spending	33%	44%	11%
	Lump-sum Tax	$572	$1,812	$74

Note: This table shows the effects of subsidies on the employment rate (percent point change), output, and welfare of the economy. The figures are average over 1968-2010.

subsidy program. The moving subsidy can also substantially reduce the welfare gap; the magnitude of its effect is similar to that of 10% wage subsidy.[24]

Since these policies are implemented at the federal (national) level, it is worthwhile to examine their impacts on the entire U.S. economy. Table 17 shows the subsidies' impacts on the employment rate of the economy. The 10% (20%) wage subsidy increases the employment rate of the Rust Belt by 7.1 (15.9) percentage points. Wages subsidies also increase the employment rate of the remaining parts of the U.S. This implies that the wage subsidies generate a net migration flow from the remaining parts of the U.S. to the Rust Belt; and furthermore, one that is disproportionately composed of individuals who would have remained out of the labor force in the remaining part of the U.S. were it not for the wage subsidies that enticed them into the workforce in the Rust Belt. On the other hand, the moving subsidy decreases the overall employment rate of the Rust Belt and increases the employment rate of the remaining parts of the U.S. This implies that the moving subsidy generates a different net migration flow, this one from the Rust Belt to the remaining parts of the U.S., that is disproportionately composed of individuals who would have worked in the Rust Belt were it not for the moving subsidy. The moving subsidy increases the employment rate of the total economy by reallocating people from the Rust Belt to the remaining part of the U.S. where overall employment rate is higher.

As seen in Table 17, all subsidies increase the total output as the employment rate increases. The wage subsidy disproportionately increases the output of the goods sector by increasing the employment rate of the Rust Belt, which has location-specific

[24]The moving subsidy increases the non-college-educated (college-educated) individual's mobility rate (from the Rust Belt to other areas) between ages 20 and 25 from 8% (22%) to 30% (42%). However, a 100% moving subsidy does not completely eliminate the welfare gap because of the unobserved heterogeneity in preference for location. Individuals who reside in the Rust Belt at age 20 are more likely to be the type of a person who has a higher preference for the Rust Belt.

advantage in producing goods. On the other hand, the output of the goods sector decresases under the moving subsidy because the workforce in the Rust Belt migrates to the remaining parts of the U.S. in which the goods-sector accounts for a relatively small proportion of production.

Table 17 also shows the subsidies' impacts on the welfare of the economy. The 10% (20%) wage subsidy results in a 0.39% (1.72%) decrease in the total welfare. The welfare loss amounts to 33% (44%) of total spending under the 10% (20%) wage subsidy program.[25] The moving subsidy reduces the total welfare of the economy by 0.03 percent. As seen in Table 17, the wage subsidy programs for the Rust Belt impose a very high tax burden on individuals in the economy. To finance the 10% and 20% wage subsidies, all the individuals in this economy have to pay $572 or $1,812 respectively each year. However, though the cost of the moving subsidy is much smaller ($74) than that of 10% wage subsidy, it mitigates the welfare gap to a similar extent. The moving subsidy program results in relatively smaller cost because it is specifically targeted to the small proportion of the total population who actually move out of the Rust Belt at age 25.

There has been a long-running debate on whether the federal government should undertake policies aimed at strengthening the economies of particular localities or regions, and I investigate the issue as follows;[26] (i) Are the policies able to change outcomes in the targeted area? I find that wage subsidies can significantly improve the outcome of the Rust Belt.[27] (ii) Are the individuals in the targeted area eventually

[25] Although the policy environments are different, my estimates of the welfare loss of wage subsidies are comparable to the estimates of Busso, Gregory, and Kline (2013) based on the Empowerment Zone program. They approximate the deadweight loss using a set of reduced from elasticities as in Chetty (2009). Depending on the estimate of the elasticities, their deadweight loss estimates range from 13% to 48% of the subsidy spending.

[26] See Glaeser and Gottlieb (2008).

[27] Some large-scale place-based policies (for example, Appalachian Regional Commission) have had

better off? Unlike the predictions of a typical model in which individuals are perfectly mobile, I find substantial welfare inequality across regions because of the huge mobility barriers. Wage subsidies and moving subsidies can significantly mitigate the welfare gap. (iii) Are the policies able to increase the welfare of the entire economy? I find no evidence of welfare improvement, even after accounting for the agglomeration externality. However, the wage subsidies significantly increase the employment rate and output of the economy. Therefore, it is at least more efficient than the pure transfer of income across regions.

7 Conclusion

This paper develops and structurally estimates a dynamic spatial equilibrium model to study the causes, welfare effects, and policy implications of the decline of the Rust Belt area in the United States. The model consists of a multi-region, multi-sector economy comprised of overlapping generations of heterogeneous individuals. Based on the estimated model, I assess the causes of the decline of the Rust Belt. I find that 50 percent of the decline in the Rust Belt's share of output is due to the reduction in its location-specific advantage in the goods-producing sector. The transition of the U.S. economy to a service sector economy due to technological change explains 25 percent of the decline. The third important factor that explains the decline of the Rust Belt is the growth of the share of college-educated people in the general U.S. population.

I investigate the welfare effects of the decline of the Rust Belt. I find that the

little impact, possibly because they distribute modest amount of money over a vast region. Some targeted policies such as Empowerment Zones seem to have some discernible effects (Glaeser and Gottlieb, 2008).

average welfare of individuals who resided in the Rust Belt at the age of 20 is 2 to 4 percent lower than that of their counterparts in other areas of the U.S. The regional difference in welfare for older individuals who are less mobile is significantly higher; the gap for them increased by up to 9.7 percent of lifetime welfare. It is also larger for less-educated individuals who are estimated to have higher mobility costs. I then conduct a variety of counterfactual policy experiments. Policy experiments show that the wage subsidies significantly reduce the welfare gap between the two areas, and increase the employment rate and output of the total economy. I also find that migration subsidies can mitigate the welfare gap with relatively smaller costs.

There are a number of important avenues for future research. First, this paper studies the welfare effects of the decline of the Rust Belt while taking the individual's education level as given. Endogenous schooling choices may play an important role as insurance against regional labor demand shifts. For example, a Rust Belt-born youth may choose to attend college in response to a negative labor demand shift that has more impact on relatively immobile non-college-educated individuals. At the policy level, a policy that helps individuals in the Rust Belt to attend college by subsidizing tuition costs could then be considered. Second, for computational reasons, I study a general equilibrium of only two regions. Breaking down the non-Rust Belt area into several subregions may provide a deeper understanding of migration decisions in response to regional labor demand shocks. For example, the coastal region and southern region of the U.S. have distinct characteristics, such as wages, housing rents, and sector composition; thus migrants to these two areas from the Rust Belt may significantly vary.

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A Additional Model Specifications

Production Fuction

$$\alpha^1_{jt} = \begin{cases} \alpha^1_{j0} & \text{if } t < 1960 \\ \alpha^1_{j0} + \alpha^1_{j1}(t-1960) & \text{if } 1960 \leq t < 1980 \\ \alpha^1_{j0} + 20\alpha^1_{j1} + \alpha^1_{j2}(t-1980) & \text{if } 1980 \leq t \leq 2010 \end{cases} \tag{11}$$

$$\alpha^2_{jt} = \begin{cases} \alpha^2_{j0} & \text{if } t < 1960 \\ \alpha^2_{j0} + \alpha^2_{j1}(t-1960) & \text{if } 1960 \leq t < 1980 \\ \alpha^2_{j0} + 20\alpha^2_{j1} + \alpha^2_{j2}(t-1980) & \text{if } 1980 \leq t \leq 2010 \end{cases} \tag{12}$$

I adopt the following normalization

$$B_{2jt} = 1 \quad \forall j, t$$

Specifically,

$$\log B_{1jt} = \begin{cases} b_{j0} & \text{if } t < 1960 \\ b_{j0} + b_{j1}(t-1960) & \text{if } 1960 \leq t < 1975 \\ b_{j0} + 15b_{j1} + b_{j2}(t-1975) & \text{if } 1975 \leq t < 1980 \\ b_{j0} + 15b_{j1} + 5b_{j2} + b_{j3}(t-1980) & \text{if } 1980 \leq t < 1985 \\ b_{j0} + 15b_{j1} + 5b_{j2} + 5b_{j3} + b_{j4}(t-1985) & \text{if } 1985 \leq t < 1990 \\ b_{j0} + 15b_{j1} + 5b_{j2} + 5b_{j3} + 5b_{j4} + b_{j5}(t-1990) & \text{if } 1990 \leq t < 2000 \\ b_{j0} + 15b_{j1} + 5b_{j2} + 5b_{j3} + 5b_{j4} + 10b_{j5} + b_{j6}(t-2000) & \text{if } 2000 \leq t \leq 2010 \end{cases}$$

Mobility Costs

$$\delta_{ii'} = \begin{cases} 0 & \text{if } i = i' \\ \delta^0_{ii'} & \text{if } i \neq i',\ a = 25 \\ \exp\left(\ \delta^1_{ii'} + \delta^2_{ii'}\,(a-26)\ \right) & \text{if } i \neq i',\ a \geq 26 \\ \exp\left(\ \delta^1_{ii'} + \delta^2_{ii'}\,(a-26) + \delta^3_{ii'}\,(a-50)\ \right) & \text{if } i \neq i',\ a \geq 50 \end{cases}$$

$$\omega_{jj'} = \begin{cases} 0 & \text{if } j = j' \\ 0 & \text{if } j \neq j',\ a = 25 \\ \omega_{jj'} & \text{if } j \neq j',\ a \geq 26 \end{cases}$$

B Data Inputs

B.1 Developed Land

The amounts of land built up for residential purposes in 1976, 1992, 2001, and 2006 are calculated based on the satellite-generated data.[28] Data for 1976 and 1992 are constructed from two publicly-available remote-sensing data sets, as in Overman, Puga, and Turner (2008). Between 1976 and 2006, I imputed the missing observations using linear interpolation. For the years before 1976 and after 2006, I used the information on the number of housings units. U.S. Census Bureau provides the unit of housing for individual states from 1940.

B.2 Cohort Size

Cohort size is obtained from Vital Statistics of the United States and from U.S. Census Bureau reports.

B.3 Education Distribution

I define a "college-educated individual" as one with at least one year of college education. The distribution of schooling for each cohort is estimated from CPS and U.S. Census.

[28]The most recent of these two remote-sensing data sets, the 1992 National Land Cover Data is derived mainly from 1992 Landsat5 Thematic Mapper satellite imagery. The data for the years 2001 and 2006 was provided by Albert Saiz using the methods in Saiz (2010).

C Soution Algorithm

The solution algorithm is an extension of the method developed in Lee and Wolpin (2006).[29] Given the parameters of the model, observed sequences of output in each sector, the rental price of capital, and the supply of land in each region the algorithm consists of the following steps:

1. Choose a set of parameters for the equilibrium aggregate state variable process (10) and for the aggregate shock process (2).

2. Solve the optimization problem for each cohort that exists from $t = 1$ through $t = T$. The maximization problem can be cast as a finite horizon dynamic programming problem. The value function can be written as the maximum over alternative-specific value functions, $V_{ij}^{a}(\Omega_{at})$, i.e., the expected discounted value of alternative ij, that satisfies the Bellman equation, specifically,

$$V^{a}(\Omega_{at}) = \max_{i,j}\left[V_{ij}^{a}(\Omega_{at})\right]$$
$$V_{ij}^{a}(\Omega_{at}) = \max_{c_a,h_a} U_{ij}^{a}(c_a, h_a \mid \Omega_{at}) + \rho \mathbb{E} V\left(\Omega_{a+1,t+1} \mid d_{ij}^{a} = 1, \Omega_{at}\right).$$

[29] I assume the economy begins in 1860 when I implement the solution algorithm. The age distribution of the population is available from that time. However, I do not have data on the state space of individuals alive in 1860 or on actual sectoral output, the rental price of capital, and the supply of land that are needed for the algorithm. I assign arbitrary values for the state space to each individual aged 25–64 in 1860 when I solve the model. For example, I assign zero work experience in each sector. I assume that the capital real rental prices, cohort size, real output in the two sectors, and the supply of land in two regions between 1860 and 1900 are the same as in 1900. Since data for output by sector is available starting in 1947, sectoral output is extrapolated backward from that point. I also assume that the real rental price of capital is constant between 1900 and 1925. I also assume that the supply of land is constant between 1900 and 1940. I find that the solution of the model for the periods that the model is fitted to actual data (1968–2010) is not sensitive to the assumptions I make.

The solution to the optimization problem is in general not analytic. In solving the model numerically, the solution consists of the values of $\mathbb{E}V\left(\Omega_{a+1,t+1} \mid d^a_{ij}=1, \Omega_{at}\right)$ for all i, j, and elements of Ω_{at}.[30] The solution method proceeds by backward recursion.[31]

3. Let r^0_1, p^0_1, and y^0_1 denote the initial guesses for skill rental prices, housing rental prices and non-labor incomes at $t=1$. Given the initial guess and the distribution of state variables for each cohort alive at that time and between ages 25 and 64, simulate a sample of agents' chosen alternatives at $t=1$ by drawing from the distribution of the idiosyncratic shocks to preferences and skills. Given the simulated choices, proceed as a Gauss-Seidel algorithm. First, compute aggregate skill supplies using relation (6), and equate the marginal product of the capital in each of the four regional-production sectors to the rental price of capital, which is observed data. Equate the two production functions to the actual output in the two production sectors. Solve the equations for the optimal capital input in each region-sector and for the two aggregate shocks, z^1_1. Calculate the marginal product of the skill, at the calculated value of skill, capital, and shocks. Let r^1_1 denote the updated skill rental prices at period one.

Second, calculate rentals for capital and land using updated skill rental prices r^1_1. Compute individual non-labor income y^1_1 using the relation (9). Third, compute aggregate housing demand using the updated skill rental prices and non-labor income,

[30] I adopt the approximation method developed by Keane and Wolpin (1994) to circumvent the curse of dimensionality.

[31] The equilibrium aggregate state variable process (10) is assumed to govern the choices made by all individuals aged 25–64 through the year 2050. I need this assumption to solve the optimization problems for individuals 25–64 as of the year 2010. Therefore, I solve the optimization problem for a 64-year-old in 2050, a 63-year-old in 2049, etc. On the other hand, the optimization problem is solved for the full age distribution of 25–64 years between 1860 and 2010.

r_1^1 and y_1^1. Find the housing rental prices p_1^1 that equate supply and demand of housing services.In general, the updated aggregate state variables, $v_1^1 = (r_1^1, p_1^1, y_1^1)$, differ from the initial guesses.

4. Update the initial guesses for the aggregate state variable to be equal to v_1^1. Repeat step 3 until the sequences of aggregate state variables and aggregate shocks converge, say to v_1^* and z_1^*.

5. Guess an initial set of values for the period two aggregate state variables, say $v_2^0 = v_1^*$. Repeat steps 3–4 for $t = 2$ to obtain v_2^* and z_2^*.

6. Repeat step 5 for $t = 3, ..., T$.

7. Using the calculated series of equilibrium aggregate state variables and aggregate shocks, estimate (2), the VAR governing aggregate shocks, and (10), the process governing the equilibrium prices.

8. Using these estimates, repeat until the series of aggregate state variables and aggregates shocks converge.

D Parameter Estimates

Table 18: Production Function (1)

Parameter	Goods Sector		Services Sector	
α_0^1	0.7926	(0.00328)	0.4020	(0.00257)
α_1^1	-0.0092	(0.00003)	-0.0060	(0.00001)
α_2^1	-0.0081	(0.00003)	-0.0048	(0.00001)
α_0^2	0.1883	(0.00328)	0.2110	(0.00257)
α_1^2	0.0089	(0.00003)	0.0096	(0.00001)
α_2^2	0.0079	(0.00003)	0.0054	(0.00001)
ψ	0.2111	(0.04001)	0.0020	(0.0008)
b_0	0.0993	(0.00402)	0.0596	(0.00181)
b_1	-0.0038	(0.00006)	-0.0034	(0.00014)
b_2	-0.0086	(0.00045)	-0.0068	(0.00001)
b_3	-0.0075	(0.00009)	0.0005	(0.00026)
b_4	0.0082	(0.00019)	-0.0011	(0.00030)
b_5	0.0025	(0.00012)	0.0021	(0.00030)
b_6	-0.0048	(0.00012)	-0.0011	(0.00030)
ν_1	5.25×10^{-6}	(1.0×10^{-7})	1.0×10^{-7}	(1.0×10^{-7})
ν_2	0.0110	(0.00005)	1.0×10^{-6}	(1.5×10^{-7})
ν_3	1.5×10^{-5}	(1.8×10^{-6})	1.0×10^{-7}	(1.2×10^{-7})
ν_4	0.0135	(0.00650)	0.0001	(0.39391)

Note: This table reports estimates of the model's production function parameters. Asymptotic standard errors are reported in brackets. Equation numbers in the titles refer to the text.

Table 19: Production Shocks (2)

Parameter	Goods Sector	Services Sector
ϕ_0	-0.015	0.001
ϕ_G	-0.604	-0.228
ϕ_R	1.092	0.558
σ_G	0.012	0.000
σ_R	0.025	0.021

Note: This table reports estimates of the model's parameters in production shock process. See table 4 note.

Table 20: Type Probabilities: $\mathbb{P}\left(type = 1 \mid home, ed\right)$

home *ed* =	Non-College-Educated		College-Educated	
Rust Belt	0.38	(0.0086)	0.32	(0.0090)
Other U.S.	0.34	(0.0079)	0.29	(0.0071)

Note: This table reports estimates of the probability of two discrete unobserved types.

Table 21: Utility Parameters (3)

	Non-College		College	
Parameter	Estimate	S.E.	Estimate	S.E.
γ_{1G}	0		0	
γ_{2G}	1494	(34)	1031	(30)
γ_{1S}	920	(24)	844	(22)
γ_{2S}	1536	(35)	1209	(31)
γ_{1O}^0	9.8677	(0.0511)	10.308	(0.0491)
γ_{2O}^0	9.8803	(0.0490)	10.378	(0.0531)
γ_O^1	0.1120	(0.0021)	0.0400	(0.0014)
σ^O	2848	(48)	2848	(49)
δ_{12}^0	36315	(181)	34201	(151)
δ_{12}^1	11.096	(0.6122)	10.990	(0.7541)
δ_{12}^2	0.0220	(0.0021)	0.0260	(0.0084)
δ_{12}^3	0.0240	(0.0031)	0.0260	(0.0074)
δ_{21}^0	31288	(184)	27364	(164)
δ_{21}^1	11.069	(0.5421)	10.990	(0.5211)
δ_{21}^2	0.0100	(0.0021)	0.0280	(0.0048)
δ_{21}^3	0.0100	(0.0032)	-0.0111	(0.0014)
ω_{GS}	8180	(112)	12360	(163)
ω_{SG}	12803	(163)	10425	(150)
ω_{GO}	32835	(211)	32775	(209)

Note: This table reports estimates of the model's parameters in utility function. See table 4 note. I impose the following restriction on the sectoral mobility cost parameters, $\omega_{GO} = \omega_{OG} = \omega_{SO} = \omega_{OS}$.

Table 22: Skill Production Functions (5)

				Goods		Services	
Non-College	$\beta^i_{1\theta}$	$\theta =$	1	0		0	
			2	-0.5140	(0.1020)	0.1033	(0.0010)
	β^2_{jk}	$k =$	G	0.0093	(0.0011)	0.0045	(0.0004)
			S	0.0001	(0.0002)	0.0101	(0.0014)
	β^3_j			0.3404	(0.0127)	0.5301	(0.0098)
	β^4_j			0.0125	(0.0127)	0.0305	(0.0098)
	σ^ϵ_{1j}			0.5655	(0.0076)	0.5390	(0.0078)
	σ^ϵ_{2j}			0.5975	(0.0087)	0.6110	(0.0077)
College	$b^i_{1\theta}$	$\theta =$	1	0		0	
			2	-0.0021	(0.0001)	0.0022	(0.0001)
	β^2_{jk}	$k =$	G	0.0680	(0.0010)	0.0001	(0.0001)
			S	0.0065	(0.0004)	0.0052	(0.0007)
	β^3_j			0.2591	(0.0127)	0.3218	(0.0098)
	β^4_j			0.0055	(0.0001)	0.0095	(0.0001)
	σ^ϵ_{1j}			0.5880	(0.0069)	0.6140	(0.0071)
	σ^ϵ_{2j}			0.6485	(0.0062)	0.6300	(0.0055)

Note: This table reports estimates of the model's parameters in skill production function. See table 4 note.