Universitat Autònoma de Barcelona

# Essays in Macroeconomics and Economic Geography

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Doctoral Thesis:

# Essays in Macroeconomics and Economic Geography

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# Contents

# Introduction

In this doctoral thesis I study how barriers and distortions inherent in labor and housing markets affect aggregate productivity of a national economy. In particular, I focus on regulation of local housing supply, constraints to labor mobility across geographical regions within a country, and firm size distortions.

In Chapter 1 of this thesis, *The Rise of Housing Supply Regulation in the U.S.: Local Causes and Aggregate Implications*, I investigate the effects of the rise of regulatory restrictions on the supply of housing in recent decades in the United States. I study the implications of the rise in regulation for aggregate productivity, and for wage and house price dispersion across locations, represented by metropolitan statistical areas.

Underlying this work is the evidence that the dispersion of wages and house prices across U.S. metro areas has grown, and that the sorting of college graduates into highly productive and expensive places has become stronger since 1980 (Moretti, 2004; Berry and Glaeser, 2005; Van Nieuwerburgh and Weill, 2010; Diamond, 2016). I argue that these rising regional disparities have been amplified by the choices of residents of the most demanded metro areas to tighten regulation. To quantify this amplification effect, I build a general equilibrium model with multiple locations and heterogeneous workers. Local house prices depend on regulation, which is decided endogenously by voting: renters want less regulation and owners want more. Faster productivity growth in some locations attracts workers and raises housing prices there. High-skilled workers, being less sensitive to rising prices, sort into productive and expensive areas. The growing prices in turn make homeowners vote for stricter regulation, which raises prices even more and leads to stronger sorting and larger wage differences.

This amplification effect of endogenous regulation choices turns out to be sizable. Using the Wharton Residential Land Use Regulatory Index (Gyourko, Saiz and Summers, 2008) and observations on local housing and labor markets, as well as workers' mobility, I calibrate the model to the U.S. economy. Then I compare the benchmark model economy in 2007 to a counterfactual 2007 economy in which regulation is at the level of 1980, imputed using the model. I find that the rise in regulation accounts for 23% of the increase in wage dispersion and 85% of the growth in house price dispersion across metro areas between 1980 and 2007. Moreover, the increase in regulation led to slower productivity growth: had regulation remained at the level of 1980 in each city, aggregate productivity would be 2% higher in 2007.

These adverse effects arise because regulation is determined locally and residents in each city do not internalize the consequences of their choices for the rest of the economy. That is, each location imposes an externality on all other locations. This implies a policy intervention might reduce the externalities by lowering incentives of local governments to restrict supply. I quantitatively evaluate a federal redistribution scheme that taxes highly regulated places and provides transfers to the lightly regulated ones. I find that such policy could raise GDP by 1.5%, reduce average house prices by 25%, and lower wage and house price differences across locations.

In Chapter 2, *Opportunity to Move: Macroeconomic Effects of Relocation Subsidies*, I turn my attention to barriers that constrain geographic mobility of workers. Job opportunities differ tremendously across local labor markets in the U.S. As a result, there is a large variation in unemployment rates across locations. Given that moving involves substantial costs, both monetary and non-monetary, and is impeded by information frictions, some unemployed workers are stuck in places where suitable jobs are scarce. At the same time, the unemployment insurance system in the U.S. does not provide explicit incentives to look for jobs outside local labor markets.

In this chapter I introduce relocation subsidies, first proposed by Moretti (2012), as a supplement to conventional unemployment benefits, and study their effects on unemployment, output and welfare. To this end, I build a job search model with heterogeneous workers and multiple locations, in which migration is impeded by moving expenses, cross-location search frictions, borrowing constraints, and utility costs. I calibrate the model to the U.S. economy, and then introduce a subsidy that reimburses a part of the moving expenses to the unemployed and is financed by labor income taxes.

I find that during 2009-2011, a period of high unemployment in the aftermath of the Great Recession, a relocation subsidy that pays half of the moving expenses would lower unemployment rate by 0.36 percentage points (or 4.8%) and increase output by nearly 1%. Most importantly, these subsidies cost nothing to the taxpayer: the additional spending on the subsidies is offset by the reduction in spending on unemployment benefits. On the other hand, the policy does not seem to produce a positive welfare effect. The subsidies attract workers toward more productive places, which leads to higher housing prices there.

In Chapter 3, *Managers and Productivity Differences*, (joint with Nezih Guner and Gustavo Ventura) we investigate the determinants of productivity differences across countries. We build upon the recent literature that demonstrates that cross-country differences in the average quality of management at the firm level feed into aggregate productivity differences (Bloom and Van Reenen, 2011). We go further and propose an explanation why the average quality of managers differs across countries in the first place.

First we document that for a group of high-income countries earnings of managers tend to grow much faster over the life cycle than earnings of individuals with a non-managerial job. Moreover, the life-cycle growth of earnings of managers relative to non managers is positively correlated with a country's productivity (measured as output per worker). We interpret this evidence through the lens of an equilibrium life-cycle, span-of-control model in which managers invest in their skills. We parameterize this model with U.S. observations on managerial earnings, the size distribution of plants and macroeconomic aggregates.

Then we quantify the relative importance of exogenous productivity differences and the size-dependent distortions, emphasized in the misallocation literature, for productivity differences across countries in our sample. Our findings indicate that such distortions are critical to generate the observed variation in the growth of relative managerial earnings across countries. We find that distortions that halve the growth of the relative earnings (a move from the U.S. to Italy in our data), lead to a 27% fall in managerial quality and a 7% reduction in output – more than a half of the observed gap between the U.S. and Italy. Finally, we calculate that on average the distortions account for 42% of the cross-country variation in the productivity gap with the U.S.

# Chapter 1

# The Rise of Housing Supply Regulation in the U.S.: Local Causes and Aggregate Implications

## 1.1 Introduction

Regulation of housing supply in the U.S. has become much stricter since the 1970's. This is important because land, materials and labor are far from the only costs faced by builders: zoning laws, public opposition to new construction, and project approval delays all add significantly to the cost of providing housing. Locations also differ greatly in how strictly they regulate housing supply, and these differences have been increasing. Regulation has grown especially stringent in highly productive metropolitan areas, such as San Francisco, New York and Boston, meaning that workers often choose to live not where they are most productive but where housing is affordable.[1] The housing affordability crisis and the restrictions on housing supply in the most productive U.S. metro areas have attracted a lot of attention from the media, policymakers and academics in recent years.[2] Yet we know little about the mechanisms that make housing markets in productive places so regulated, and the magnitude of their effects on the economy as a whole.

The rise of regulation has been accompanied by a broad pattern of spatial divergence in the U.S. Since 1980, the variance of log mean hourly wages across metro areas almost doubled, while the variance of log quality-adjusted house prices more than tripled. During the same period, workers have become more sorted by skill: metro areas with a larger fraction of college-educated workers in the labor force in 1980 added more college workers over the next three decades than other metro areas.[3] Some of the previous attempts to explain these facts emphasized the role of regulatory restrictions on the supply of housing. However, those studies did not take into account the endogeneity of regulation to local characteristics, such as population size, skill mix and real estate prices. Furthermore, the existing work typically focuses on the effects of the levels of regulation rather than the effects of the increase in regulation.

This paper makes three contributions. First, it proposes an equilibrium model with multiple locations and heterogeneous workers, in which regulation in every location is

[1] This paper focuses on metropolitan statistical areas (MSAs), but uses the notions "metro area", "city" and "location" interchangeably.

[2] See, for example, The Economist (2016) and White House (2016).

[3] Moretti (2012) calls these and other related phenomena "The Great Divergence."

determined endogenously in a political process. Second, it calculates the effects of the rise of housing supply regulation in the U.S. on aggregate productivity, on the increase in wage and house price dispersion across metropolitan areas, and on the skill sorting between 1980 and 2007. Third, it quantitatively evaluates federal policies that reduce incentives of local governments to regulate housing supply, and shows that these policies could lower wage and house price dispersion across metro areas, and raise aggregate productivity.

The model has a life-cycle structure and is populated by workers with heterogeneous skills. In the first period they choose where to live, and their choice depends on wages, housing costs, and idiosyncratic location preferences. In each subsequent period they choose whether to own or rent a house. Individuals prefer to own, however purchasing a house requires a downpayment. Thus buying immediately may not be feasible and workers need to accumulate savings to afford a house. Housing is built by competitive developers. In equilibrium, house prices depend on population size and regulation. Regulation is assumed to affect the prices through the elasticity of supply. In highly regulated markets the supply of housing will be slow to react to new demand and, as a result, the prices will increase. In markets with low regulation the supply of housing will accommodate most of the rise in demand and the prices will not change much.

Regulation is determined in a political process, designed along the lines of a standard model of probabilistic voting with lobbying. Every period elections are held for local governments, and residents vote for candidates, each of which runs with a proposed level of regulation. The selected level of regulation is determined by two competing sets of interests: those of renters and those of owners. Renters prefer less regulation because this decreases rents and house prices, thereby lowering the downpayment they need to pay in case they decide to buy. Homeowners prefer more regulation as it increases the value of their houses.[4] Owners finance the candidates' campaigns with monetary contributions, and the size of the required contribution is increasing in the proposed level of regulation. Given that regulation is costly, the incentive of owners to support stricter regulation depends on how important the value of the house is in their asset portfolios and on the sensitivity of prices to changes in regulation which is higher in cities with scarce land. The ability of owners to influence local governments depends on the fraction of high-skilled workers among the homeowners, i.e. how educated they are. Therefore, in equilibrium, denser and more productive locations are more regulated.

The exogenous forces that drive the skill sorting and the rise in wage and house price dispersion are (1) changes in city-specific productivities and skill-biased technical change, (2) population growth, and (3) the increase in the share of workers with college degree. Locations where productivity is growing rapidly attract workers and, due to an increase in population density, housing there becomes more expensive. A rise in housing costs moderates the inflow of workers, but the high-skilled are not affected as much as the low-skilled, since the former spend less of their income on housing. Thus skill sorting across locations intensifies, especially if the changes in local productivity are skill-biased. Larger differences in skill ratios lead to larger differences in mean wages. What is the role of regulation? An increase in house prices after a productivity shock makes real estate a more important asset in owners' portfolios and they vote to raise regulation. Once they do so, prices rise even more and the relative inflow of high versus low skilled workers is more disproportionate. That is, endogenous regulation choices amplify the effects of changes

[4]The idea that homeowners favor stricter regulation due to their concern for the value of their property was promoted by Fischel (2001) and called the "homevoter hypothesis."

in exogenous productivities and lead to even more skill sorting, and wage and house price dispersion. Population growth makes cities more congested on average and enhances the demand for regulation. The increase in the share of college graduates improves the ability of residents to affect the decisions of local governments.

The model parameters are disciplined by a set of moments that describe local labor and housing markets in the U.S. in 2007. The calibrated economy comprises 190 metropolitan areas. As a measure of regulation, I use the Wharton Residential Land Use Regulatory Index, constructed for the year 2007 by Gyourko, Saiz and Summers (2008). The calibration only targets three moments of the observed distribution of regulation, yet the model predicts a significant portion of the observed distribution.

In order to study the effects of the *rise* in regulation, we must have data on regulation for multiple years, and such data does not exist for a broad set of metropolitan areas. However, given that the model explains well the observed variation in regulation in 2007, it can be used to impute levels of regulation for other years. Thus I construct a 1980 economy in which total population, exogenous productivities and college attainment are at the 1980 level. In this economy regulation endogenously adjusts: it is lower than in 2007 on average and the differences across locations are smaller, which is consistent with the literature on the increase in regulation. I focus on stationary spatial equilibria.[5] To evaluate the effect of the rise in regulation on the U.S. economy, I compare the benchmark economy calibrated to 2007 with the same economy in which regulation is fixed at the 1980 level predicted by the model.

I find that if regulation had not increased after 1980, the magnitude of the skill sorting would be smaller. As a result, wage inequality across cities would grow by 23% less from 1980 to 2007. The rise of regulation also led to aggregate productivity losses. Had regulation remained at the 1980 level, output would be more than 2% higher in 2007, since more workers would be able to live in highly productive but currently unaffordable cities. Absent the growth in regulation, houses would be 43% less expensive on average in 2007, while house price dispersion would increase by 85% less between 1980 and 2007. These effects are highly heterogeneous across space. If regulation had not changed since 1980, house prices in some expensive areas such as New York, San Francisco and Miami would be more than 60% lower, whereas in many inexpensive areas such as Dallas and Houston they would not change much.

The main reason why the rise of regulation since 1980 has had negative aggregate effects, according to this paper's model, is that local governments choose regulation independently and disregard the implications of their decisions on the rest of the economy. In other words, residents of every city impose an externality on the residents of other cities. The existence of externalities implies that national-level policies might improve aggregate outcomes. To evaluate the effectiveness of such policies, I study two alternative arrangements. In the first, the federal government sets an exogenous limit on regulation which no city can exceed. In the second, the government runs a redistributive scheme which taxes owners of expensive real estate, which typically concentrate in highly regulated cities, and provides transfers to the owners of cheap real estate. These policies raise output and wages by about 1.5%, reduce average house prices by 20-25%, and lead to a substantial fall in house price dispersion and a moderate reduction in wage inequality.

[5] By focusing on stationary environment I restrict my attention to long-term effects of regulation. However, elasticity of housing supply also matters for the ability of a city to withstand short-term fluctuations: Arias, Gascon and Rapach (2016) find that areas with less elastic supply experience more severe recessions.

The effects, again, are heterogeneous across cities, and the policies mostly affect large expensive metro areas.

This paper is organized as follows. The rest of this section places this work in the existing literature. Section 1.2 describes the data and provides empirical evidence about local labor and housing markets, and land use regulation. Section 2.2 describes the model. Section 1.4 discusses the values of model parameters. Section 1.5 describes the benchmark economy and presents comparative static effects of regulation. Section 1.6 evaluates the role of the rise of regulation for aggregate productivity, and the increase in wage and house price dispersion from 1980 to 2007. Section 1.7 investigates hypothetical interventions of a central government into regulatory decisions of local governments. Finally, Section 1.8 concludes.

### 1.1.1 Literature

This paper is connected to several strands of literature.[6] First, it draws on the evidence on the effects of land use regulation on housing supply and prices at the local level. This literature, summarized in Quigley and Rosenthal (2005), typically finds that stricter regulation causes higher land and house prices and lower supply of new structures.[7] Saiz (2010) concludes that both geographic and regulatory constraints are central in explaining price differences across metropolitan areas in the U.S. Both types of constraints are also crucial in the current paper.

This paper contributes to a more recent literature that looks at general equilibrium implications of regulation. The common theme of this work is that regulation leads to misallocation of labor by preventing workers from living in productive places, and may therefore have aggregate effects.[8] Ganong and Shoag (2015) build a time-series index of regulation at the state level, and show that regulation has risen on average and has become more different across U.S. states. Their paper argues that the increase in regulation has halted cross-state income convergence and contributed to the rising wage inequality since the 1970's. Hsieh and Moretti (2015), using a quantitative spatial equilibrium model, argue that reducing regulation in just three highly productive metro areas with sky-high house prices – New York, San Francisco and San Jose – to the median U.S. level would lead to a nearly 10% rise in aggregate output in 2009 due to a massive inflow of workers who previously found these places unaffordable.[9] The key driving forces of the mechanisms in these papers are also present in the current paper, however the previous work treats regulation as exogenous and remains silent on why some cities are more regulated than

[6] Gyourko and Molloy (2015) provide an excellent review of the literature on land use regulation and its effects on housing and labor markets.

[7] See also Mayer and Somerville (2000) and Ihlanfeldt (2007).

[8] Even if residential land use regulation has negative aggregate effects, it need not lead to welfare losses, since the stated aim of most land use regulation is to protect residents from negative externalities that arise from congestion or adjacent non-residential land use. Yet Turner, Haughwout and van der Klaauw (2014) and Albouy and Ehrlich (2016) find negative welfare effects. A separate literature models emergence of land use regulation in response to negative local externalities – see Duranton and Puga (2015) for a review. Stringent land use regulation also drives urban segregation by income, according to the findings of Lens and Monkkonen (2016).

[9] The output effect in their paper is much larger than what this paper finds, mostly due to the assumption of free labor mobility. In their framework moderate changes in house prices may lead to a massive labor reallocation. In this paper individuals have strong idiosyncratic location preferences and even large changes in wages and prices only result in modest changes in the distribution of labor across space.

others.[10]

At the same time, a few papers modeled endogenous emergence of regulation in a spatial equilibrium setting. However, unlike this paper, they typically propose a theoretical mechanism without quantitatively evaluating the effects of regulation. Hilber and Robert-Nicoud (2013) study a lobbying game in which landowners, who prefer more regulation, compete with developers, who prefer less.[11] In equilibrium locations with better amenities are both more developed and more regulated. Their model is consistent with the observed positive relationship between amenities and regulation. In a voting model of Ortalo-Magné and Prat (2014), which formalizes the "homevoter hypothesis" of Fischel (2001), undersupply of housing occurs when the median voter is heavily invested in real estate. In this case, new construction reduces house values and hurts the median voter.

This paper joins the literature on the causes of the rise in house price dispersion across metro areas since around 1980. Besides, it contributes to a large literature on the causes of the escalation in income inequality since late 1970's. Glaeser, Gyourko and Saks (2005b) and Albouy and Ehrlich (2016) find that the costs incurred by developers due to regulation vary greatly across metro areas, hence a large part of the price dispersion must be due to differences in regulation. Indeed, Gyourko, Mayer and Sinai (2013) show that a model in which local differences in supply elasticities are combined with the increase in exogenous wage inequality can explain about 80% of the rise in the price dispersion from 1970 to 2000, which is very close to the number this paper finds. At the same time, Van Nieuwerburgh and Weill (2010) find that most of the rise in house price dispersion can be explained by growing productivity differences across locations, though their mechanism relies on inelastic housing supply which may arise due to regulation. Moretti (2013) was one of the first studies to recognize that the rising income differences partly stem from the growing differences in the cost of living across metro areas. His paper finds that the cost-of-living differences account for 25-30% of the increase in the college wage gap between 1980 and 2000. Baum-Snow and Pavan (2013) argue that the increase in wage inequality is partly a big city phenomenon: they find that at least 23% of the growth in the variance of log wages between 1979 and 2007 is explained by the faster growth in wage inequality in larger cities than in smaller cities. The current paper, by proposing a mechanism that generates regulation, emphasizes the feedback effect between the growing concentration of skills, the rising dispersion of house prices and incomes, and the increasingly different regulation levels and costs of living across communities.

This work is also related to efforts to understand why regulation has become more stringent in recent decades. Glaeser, Gyourko and Saks (2005a) argue that the most likely reasons are that residents' groups have become more politically influential and that the ability of developers to affect decisions of local planning boards has diminished. Fischel (2015) also links the rise of regulation to suburbanization and the increase of house values in portfolios of homeowners in the 1970s, both of which increased owners' incentives to undertake actions that preserve or raise the values of their houses. However, these mechanisms have not been quantitatively evaluated within an equilibrium framework in which regulation is chosen endogenously. The political economy model in this paper accommodates these mechanisms, and quantifies their general equilibrium effects.

[10] A related body of research connects labor misallocation across space to differences in taxation (Albouy (2009), Eeckhout and Guner (2015) and Fajgelbaum, Morales, Suárez Serrato and Zidar (2016)) and constraints to workers' mobility (Şahin, Song, Topa and Violante (2014) and Chapter 2 of this thesis).

[11] Earlier work includes Brueckner (1995), Helsley and Strange (1995), Calabrese, Epple and Romano (2007), and Solé-Ollé and Viladecans-Marsal (2012).

Finally, this paper is connected to the literature in macroeconomics that investigates the effects of homeownership on labor markets. According to Head and Lloyd-Ellis (2012) and Karahan and Rhee (2014), ownership may contribute to aggregate unemployment, especially during recessions. Ferreira, Gyourko and Tracy (2010) and Schulhofer-Wohl (2012) study the role of ownership for geographic mobility and the ability of localities to respond to economic fluctuations. In the current paper, homeownership affects local house prices, and thus labor supply, via a political process that determines how regulated housing supply is.

## 1.2 Data and Empirical Evidence

In this section I describe the data used in this paper and present the empirical facts that motivate and discipline the model and the quantitative analysis.

### 1.2.1 Data

The number of workers, wages and housing prices for each metropolitan area are calculated using individual level data from the 5% samples of the Census in 1980, 1990 and 2000, and the 3% sample of the American Community Survey in 2005-2007 from the IPUMS (Ruggles et al, 2015). The sample used in this paper is limited to heads of household and their spouses in prime working age (from 25 to 64 years old), who are employed and worked at least 35 hours a week for at least 27 weeks in the sample year. I exclude individuals who live in group quarters, work for the government or the military, and those who live in farm houses, mobile homes, trailers, boats, tents, etc. I also exclude observations with reported annual wage and salary income that is equivalent to less than half of the minimum federal hourly wage.

As the measure of regulation I use the Wharton Residential Land Use Regulatory Index (WRLURI) developed by Gyourko, Saiz and Summers (2008), based on a survey they conducted in 2007.[12] The survey questionnaire was sent to an official responsible for planning and zoning in every municipality in the U.S. and contained a broad set of questions about local rules of residential land use. The answers were then used to create eleven indices that measure different aspects of regulation, as well as a single index of regulation (the WRLURI) that summarizes the strictness of regulatory environment for each municipality.

The geographical unit of analysis is metropolitan statistical area (MSA). A metropolitan area consists of a county or several adjacent counties, and is defined by the Census Bureau such that the population of its urban core area is at least 50,000 and job commuting flows between the counties are sufficient for the area to be considered a single labor market. There are only 190 MSAs in the 48 contiguous U.S. states such that (1) they can be identified in the IPUMS Census/ACS samples in all years since 1980 and (2) the Wharton Index is available for municipalities in an MSA. Thus the sample used in this paper only includes individuals that reside in one of these 190 MSAs. The population of these 190 MSAs makes up 85% of the metro area population and 71% of total population of the contiguous U.S. in 2007.

[12] A few earlier surveys were conducted since the 1970's and are summarized in Saks (2008). Yet, compared to the WRLURI, they are more limited in the number of geographical units or the types of regulation.

An MSA is defined by the U.S. Census Bureau using job commuting patterns and thus constitutes a contiguous labor market. At the same time, land use regulation is determined by municipal governments, and large metro areas often consist of more than a hundred municipalities. To focus on labor and housing markets and to abstract from the complexity associated with modeling a two-level geography, I assume that regulation is chosen at the MSA level and use the Wharton Index aggregated to the MSA level. Gyourko, Saiz and Summers (2008) find that differences in regulation within metro areas are smaller than the differences across metro areas.[13]

Observations with a college degree and above are defined as high-skilled. All others are defined as low-skilled. Hourly wage is calculated as the reported annual wage income divided by the number of weeks worked per year times the usual hours worked per week. Housing prices are calculated as follows. For each metro area I construct quality-adjusted owner-occupied and rental price indices using self-reported house values and rent payments.[14] Each index is calculated using a hedonic regression that controls for housing unit characteristics, such as the number of rooms, the number of units in the building, and the construction year. I follow the approach used in Eeckhout, Pinheiro and Schmidheiny (2014).

### 1.2.2 Facts on Labor and Housing Markets

The following three facts characterize different aspects of regional divergence in the U.S. from 1980 to 2007.[15]

1. *The dispersion of house prices across metro areas surged.* From 1980 to 2007, the variance of log quality-adjusted house price index jumped by 258% (Figure 1.1). The increase in the mean and the variance of prices was faster than that of wages. As a result, real house prices increased by 44% on average, while their standard deviation jumped by 150%.[16]

2. *The dispersion of wages across metro areas increased.* The variance of log mean hourly wages across metro areas went up from 0.0085 in 1980 to 0.0167 in 2007 (Figure 1.2). Most of the increase in the dispersion of both wages and house prices occurred at the right tail of the distribution, i.e. was driven by productive and expensive areas, such as New York, San Francisco and San Diego.

[13]The number of municipalities in a metro area and the distribution of population between them may matter. Fischel (2008) shows that MSAs with more fragmented governments, i.e. with many small suburbs, are more likely to have stringent development restrictions. The primary reason is that in larger jurisdictions developers are more influential and homeowners find it more difficult to organize around a common goal.

[14]Self-reported prices have been widely used in the literature in cases when other measures were not available. Kiel and Zabel (1999) show that, while self-reported prices are 3-8% higher than actual prices, the size of the bias does not depend on observable owners' characteristics and location. Thus, for the purposes of comparison across metro areas, self-reported prices are good proxies for market prices.

[15]These facts have been documented and studied before. The rise in wage and house price dispersion was analyzed in Van Nieuwerburgh and Weill (2010) and Hsieh and Moretti (2015). The increase in skill sorting across MSAs was first reported and studied by Moretti (2004) and Berry and Glaeser (2005). Shapiro (2006) finds that metro areas with higher shares of college graduates experience faster wage and house price growth. Diamond (2016) argues that the skill sorting that emerges from rising productivity differences across cities is amplified by endogenous skill-specific amenities.

[16]The change in real prices is measured as the growth rate of mean quality-adjusted house price in an MSA divided by the growth rate of mean hourly wage.

3. *Skill sorting across metro areas intensified.* Metro areas where high share of college graduates in 1980 saw a faster increase in the share of college graduates over 1980-2007 than other metro areas (Figure 1.3).

This paper focuses on the role of housing supply regulation in explaining these facts. First, I argue that these three facts help explain why housing supply regulation has increased and has become more different across cities. Second, I claim that the proposed political economy mechanism that determines regulation amplifies the effects of factors exogenous in the model, such as location-specific productivities, on these facts. Other empirical facts relevant for this paper are the increase in the share of college graduates from 0.255 to 0.398 between 1980 and 2007, and the increase of the log of the ratio of the mean wage of college graduates to the mean wage of the individuals without a college degree increased from 0.368 to 0.609 during the same period.[17] Table 1.1 summarizes these and other empirical facts.

The next set of facts relates the stringency of land use regulation, as measured by the Wharton Index, to labor and housing market outcomes at the metropolitan area level. These observations inform the political economy model of regulation in this paper.

4. *Larger and denser metro areas are more regulated.* The correlation between the Wharton Index and the workforce size is 0.25, whereas the correlation between the Wharton Index and the population density is 0.34. (Figures 1.4 and 1.5).

5. *High-income expensive metro areas are more regulated.* Regulation is positively correlated with mean wages (0.41) and house prices (0.56), even controlling for city size (Figures 1.6 and 1.7). However, most of the correlation between wages and regulation is due to the fact that wage differences across metro areas partly reflect differences in housing prices. When real wages are used instead, the correlation drops to 0.27.

6. *Highly regulated metro areas have less homeowners.* Regulation is negatively correlated with homeownership (Figure 1.8). On the one hand, higher ownership rates should lead to more regulation as owners are likely to be interested in restricting new construction. On the other hand, high regulation leads to higher house prices and makes ownership unaffordable for a larger share of population. The negative correlation suggests that the second effect dominates in the data.

7. *Regulation rose and became more different across locations.* While there is no comprehensive widely-accepted measure of land use regulation available across time and space, there is evidence that confirms that the regulatory barriers have tightened in the second half of the 20th century.[18] Ganong and Shoag (2015) constructed a time series measure of regulation at the state level.[19] Their paper finds that regulation has been increasing since at least 1940 and that most of the increase occurred between 1970 and 1990. In addition local differences in regulation have been widening, as in some states regulation grew faster than in others (Figure 1.9).[20] Morrow

[17]These numbers are calculated for the sample of individuals I use in this paper. See Section 1.2.1.

[18]McLaughlin (2012) reviews the existing evidence in the U.S. and other countries.

[19]They counted the number of cases in state appellate courts that contained the phrase "land use" and used their fraction among all cases as a measure of the level of stringency of land use regulation.

[20]Unfortunately, a similar panel data does not exist for MSAs. Given significant variation in regulation within states, I cannot use the index of Ganong and Shoag (2015) to investigate dynamic relationships between regulation and labor and housing market outcomes at the MSA level.

(2013) documents that the city of Los Angeles was zoned to accommodate about 10 mln inhabitants in 1960, at the time when its population was 2.5 mln.[21] However, due to rising regulation in the following years, the city's residential capacity shrank to just 3.9 mln in 1990, while its population grew to 3.5 mln. This implies that to expand population further the city must re-zone the land for denser use, an onerous task due to opposition by local homeowners. There is also indirect evidence on the rise of regulation. Gyourko and Molloy (2015) document a rising gap between real construction costs and real house prices since 1980. Noting that construction is a competitive industry with many small firms, they argue that the most likely reason for the widening gap is the rise of regulation.

## 1.3 Environment

### 1.3.1 Workers and Markets

The economy comprises $M$ metropolitan areas, indexed by $m \in \{1, ..., M\} \equiv \mathcal{M}$. A metro area is an "island" without any internal structure, as in Lucas and Prescott (1974). Every metro area is populated by a measure $N_m$ of workers, and has its own labor and housing markets. Individuals live and work for $T$ periods, and their age is indexed by $a$. They are endowed with a skill level, low or high, $s \in \{L, H\}$. Skill level is fixed for lifetime. Measures of each skill in the economy are given exogenously by $\lambda_L$ and $\lambda_H$.

**Consumption and savings.** Workers consume a homogeneous consumption good and one unit of housing. Since housing consumption is fixed, the share of housing in expenditures falls with income.[22] Housing can be rented or owned, but ownership provides additional utility $\gamma$. An individual must live in the same location where she works. The utility function is given by

$$u(c, h) = \ln c + \mathbb{I}_{h\geq 1}\gamma,$$

where $h \in \{0, ..., T-1\}$ indicates how long the worker has owned the house, $h = 0$ indicating that the worker rents. Future utility is discounted with factor $\beta$. Individuals can save $k$ units of their income and receive return $i^k$ on their assets next period. Borrowing is not allowed, except for taking out a mortgage to purchase a house.

**Production.** In every city, there is a representative firm that uses capital and labor to produce a homogeneous consumption good. The good is the numeraire, traded across cities at zero cost. The production technology is given by

$$Y_m = K_m^\alpha \left(\tilde{N}_{mL}^\eta + \tilde{N}_{mH}^\eta\right)^{\frac{1-\alpha}{\eta}}, \tag{1.3.1}$$

where $\tilde{N}_{ms} \equiv \sum_{a=1}^{T} g_{msa} N_{msa}$ is local supply of $s$-skilled labor in efficiency units, and $g_{msa}$ is the productivity of an individual of skill $s$ and age $a$ working in metro area $m$. The elasticity of substitution between the two types of labor is $\frac{1}{1-\eta}$.

[21]Every municipality in the U.S. is divided into zones. Each zone is characterized by requirements on minimum land area of a lot, maximum height, and often number of households that can occupy a lot. Thus it is possible to calculate the maximum population capacity of a municipality, given existing zoning.

[22]This feature is consistent with the empirical observation that the share of income spent on housing is decreasing with income. See Ganong and Shoag (2015).

Capital is supplied perfectly elastically at an exogenous interest rate $i^k$ in all locations. The equilibrium wage is given by

$$w_{msa} = (1-\alpha)\left(\frac{\alpha}{i^k}\right)^{\frac{\alpha}{1-\alpha}} g_{msa}\left(1+\left(\frac{\tilde{N}_{ms'}}{\tilde{N}_{ms}}\right)^{\eta}\right)^{\frac{1-\eta}{\eta}}, \qquad (1.3.2)$$

where $s' = H$ if $s = L$, and $s' = L$ otherwise.

The model of production does not feature agglomeration externalities, hence they implicitly show up as a part of city-specific productivity shifters $g_{msa}$. In Section 1.6, I explain why including agglomeration would not change the quantitative results of this paper.

**Construction.** The model of the construction sector is based on the standard Rosen-Roback model in urban economics.[23] I extend their basic model by introducing dynamics and two types of housing.

Every individual must either rent or own exactly one unit of housing in the city where he works. In every city, there is a continuum of construction firms (*developers*). Each developer specializes either in owner-occupied ($O$) or rental ($R$) housing. Within these types housing is homogeneous in size and quality. The developers of both types sell the newly constructed housing units to *real estate managers* (described later in this section) who then sell or lease it to workers. The developers of owner-occupied housing sell the units at price $p_{mt}$ in period $t$. The developers of rental housing sell the units at the price equal to discounted rents: $\sum_{v=t}^{\infty}\rho^{v-t}r_{mv}$. In a stationary environment this price is equal to $\frac{1}{1-\rho}r_{mt}$. Housing does not depreciate and can be destroyed at no cost. I assume that the cost of maintenance of vacant houses is high enough so that unoccupied housing is always destroyed. A city has time-invariant land endowment $\Lambda_m$. The land is owned by infinitely lived absentee landowners and leased to the developers at price $r^L_{mt}$. The landowners incur no costs when leasing land and discount future by factor $\rho$.

As in the Rosen-Roback model, I assume that housing development is continuous in horizontal and vertical dimensions. Let $J_{m,t-1}$ be the land area developed at the beginning of period $t$, and $Q^O_{m,t-1}$ and $Q^R_{m,t-1}$ be the quantity of owner-occupied and rental housing per unit of land at the beginning of the period. Then the total quantity of housing in city $m$ at the beginning of period $t$ is: $J_{m,t-1}(Q^O_{m,t-1}+Q^R_{m,t-1})$. In each period developers may increase the quantity of existing housing based on changes in demand by building $q^j_{mt}J_{mt}$ units of type $j \in \{R, O\}$. The construction technology uses the consumption good and land. The cost of building $q^j_{mt}$ units of housing on one unit of land is increasing and convex in the amount of existing housing of all types on the unit of land:

$$C^j_{mt}\left(q^j_{mt}\right) \equiv \chi^j_{mt}\left(Q^R_{m,t-1}+Q^O_{m,t-1}+q^R_{mt}+q^O_{mt}\right)^{\zeta_{mt}},$$

where $\chi^j_{mt}$ captures physical construction costs, while $\zeta_{mt} > 1$ determines how fast the cost increases with congestion. When a developer of one type of housing chooses to build more units, it raises the construction cost for the developers of the other type by increasing congestion in the city. Due to convex construction costs and given that landowners do not incur any costs, in equilibrium all land in the city will be developed, i.e. $J_{mt} = \Lambda_m$ for all $t$.[24] This means that the optimization problem of developers simplifies to the choice

[23] See Rosen (1979), Roback (1982) and Glaeser (2008) for details.

[24] Suppose that only a fraction of available land is developed. Then the owners of undeveloped land will offer their plots at a lower price and attract construction.

of quantity of construction per unit of land. This also implies that the model predicts sprawling urban growth: initially a city expands by using more land and then by building more densely.

Consider a stationary environment in which rents and costs are the same every period. Developers take housing price $p_{mt}$, rent $r_{mt}$ and the cost of land $r^L_{mt}$ as given, and choose construction $q^j_{mt}$ per unit of land to maximize profits. The profit of the developer of owner-occupied housing is

$$\pi^O_{mt} = p_m q^O_{mt}\Lambda_m - C^O_{mt}\left(q^O_{mt}\right)\Lambda_m - \frac{r^L_{mt}}{1-\rho}\Lambda_m.$$

The profit of the developer of rental housing is given by

$$\pi^R_{mt} = \frac{r_{mt}}{1-\rho} q^R_{mt}\Lambda_m - C^R_{mt}\left(q^R_{mt}\right)\Lambda_m - \frac{r^L_{mt}}{1-\rho}\Lambda_m.$$

In equilibrium both housing markets clear. The supply of owner-occupied housing is $Q^O_{m,t-1} + q^O_{mt}$ and, since everyone consumes one unit, the demand is equal to the number of owners in the city, $N^O_{mt}$. Hence $Q^O_{m,t-1} + q^O_{mt} = N^O_{mt}$. Similarly, for rental housing $Q^R_{m,t-1} + q^R_{mt} = N^R_{mt}$. However, since the cost function depends on the total quantity of housing, the prices of each type of housing depend on the total demand for both types of housing, $N_{mt} = N^O_{mt} + N^R_{mt}$. Local demand for each type of housing, $N^O_{mt}$ and $N^R_{mt}$, is endogenous and arises from individual choices described in detail in Section 1.3.2. The equilibrium price of a house is

$$p_{mt} = \chi^O_{mt}\zeta_{mt}\left(\frac{N_{mt}}{\Lambda_m}\right)^{\zeta_{mt}-1}. \tag{1.3.3}$$

The equilibrium rent is given by

$$\frac{1}{1-\rho} r_{mt} = \chi^R_{mt}\zeta_{mt}\left(\frac{N_{mt}}{\Lambda_m}\right)^{\zeta_{mt}-1}. \tag{1.3.4}$$

In this model, price-to-rent ratios are exogenous and given by $\frac{\chi^O_{mt}}{(1-\rho)\chi^R_{mt}}$. The differences in price-to-rent ratios across cities arise from the differences in physical construction costs $\chi^j_{mt}$.[25] The price elasticity of housing supply in city $m$ is given by $\frac{1}{\zeta_{mt}-1}$.

**Homeownership and real estate managers.** All individuals have access to a mortgage facility which allows to extend payments for the house over $\kappa$ periods. If a renter decides to buy a house in period $t$, he must pay $\delta p_{mt}$ where $\delta \in (0,1)$ is the downpayment rate. In each period $t+1, ..., t+\kappa$ the worker pays $(1+i^h)\mu p_{mt}$, where $i^h$ is the mortgage interest rate and $\mu$ is the fraction of the house value to be paid off each period. Parameters $\mu$ and $\kappa$ must satisfy $\delta + \mu\kappa = 1$. The equilibrium house price may change, but the worker always repays mortgage based on the purchase price. Starting from period $t+\kappa+1$ the worker fully owns the house. An individual who has owned a house for $h$ periods can sell it any time at current equilibrium price $p_{m,t+h}$. If the mortgage was not fully paid, the proceeds from the sale are equal to the fraction of the value of the house which has been repaid, $(\delta + \mu h)p_{m,t+h}$.

[25] I do not model endogenous determination of price-to-rent ratios. One way to obtain differences in price-to-rent ratios is to have different expected growth rates of rents across cities, as in Campbell, Davis, Gallin and Martin (2009). However, this would rule out stationary equilibria.

Developers sell the newly constructed units to the infinitely-lived competitive real estate managers (REMs). Then the REMs issue mortgages and hand over owner-occupied houses to owners, and lease rental houses to renters. When a house is sold on the secondary market, the REM pays $p_{m,t+h}\min\{\delta+\mu h, 1\}$ to the seller. The buyer pays the downpayment to the REM immediately and mortgage payments over the next $\kappa$ periods.

I assume that the cost of default is large enough that buyers always fulfil their debt obligations to REMs. REMs bear all the risks associated with price changes: upside risks if the equilibrium price falls and incoming mortgage payments exceed loans to new homeowners, and downside risks in the opposite case. These risks are uninsurable, however in a stationary environment there is no price risk, and hence the REMs do not charge any risk premium.

### 1.3.2 Workers' Decisions

**Choice of location.** The measure of workers born in each location is exogenous and is described by the distribution $\{\psi_m\}_{m\in\mathcal{M}}$. At the very beginning of the first period, an individual is born in city $m^*$ and must choose the location of residence $m$. This decision is irreversible – it is not possible to move later in life. The location choice is affected by three factors. First, at the moment of birth an individual receives a vector of *i.i.d.* utility shocks $\varepsilon$ which is associated with living in each of the cities in the economy. This shock should be interpreted as the idiosyncratic utility cost or benefit of living in a given city. Second, individuals are attached to their birthplaces: choosing to live in a location other than the birthplace implies a disutility $\xi$, which is subtracted from utility.[26] Finally, workers compare the attractiveness of labor and housing markets in different cities. They take into account the lifetime wage profile $\{w_{msa}\}_{a=1}^{T}$ each city $m$ offers to workers of their skill group $s$, and the costs of renting and buying a house: $r_m$ and $p_m$. When choosing a city, workers not only consider the level of housing costs but also whether they will be able to afford the downpayment and purchase a house soon enough in the life cycle. This is because, all else equal, owning is preferred to renting. First, it brings additional utility $\gamma$. Second, a house is an asset that can be sold, and the proceeds from the sale can be consumed. Taking all these considerations into account, an individual moves out of city of birth if either he likes another location $m$ for idiosyncratic reasons (high $\varepsilon_m$ relative to $\varepsilon_{m^*}$) or labor and housing market conditions in $m$ are much better than in $m^*$. Individuals are born with no real estate property and thus must rent during the first period of their lives.

**Timing and value functions.** Every period an individual works and receives salary $w_{msa}$. Then he decides (1) how much to consume, (2) how much to save, and (3) whether to rent or own housing, in order to maximize the expected discounted lifetime utility. Renters pay rent $r_m$. Owners pay mortgage with interest $(1+i^h)\mu p_{m,t-h}$ on the house bought $h$ periods ago. A renter may decide to buy a house at any age, just as an owner may decide to sell the house and become a renter. The transactions that involve changes in homeownership status occur in the current period, but the actual changes in the status are effective next period. In the last period $T$, an owner pays the mortgage (if it has not been paid off), sells the house and consumes the proceeds. At the end of each period,

[26] For convenience, I assume that the disutility is only experienced in the first period. However, since migration in later periods is not allowed and since $\xi$ is additive, this is equivalent to a disutility every period.

developers adjust supply of housing of each type to satisfy the demand from new and existing residents.

There is no aggregate uncertainty, and the only source of individual uncertainty are the location-specific utility shocks.[27] The individual state is $x = (m^*, s; m, a, k, h)$. Birth location $m^*$ and skill level $s$ are fixed for life. Residence $m$ is chosen in the first period and remains fixed, while age $a$, savings $k$, and the length of ownership $h$ change every period. The aggregate state is described by the distribution of labor across individual states $\Phi : \mathcal{X} \to \mathbb{R}_+$, where $\mathcal{X} \equiv \mathcal{M} \times \{L, H\} \times \mathcal{M} \times \{1, ..., T\} \times [0, \infty) \times \{0, ..., T-1\}$ is the space of individual states. Since the environment is stationary, $a$ indexes both age and time.

The value function of a renter in period $1 \leq a < T$ describes the decision between becoming a homeowner and remaining a renter, and the decision on the next period's savings. Wages $w_{msa}(\Phi)$, rents $r_{ma}(\Phi)$ and house prices $p_{ma}(\Phi)$ depend on the distribution of population across individual states $\Phi$. When making decisions, individuals take the wages, the rents and the prices as given. There is a tradeoff between becoming an owner and remaining a renter. On the one hand, ownership may provide a higher expected future utility $\mathrm{E}\left[V^O\right]$. On the other hand, in addition to the rent, the renter must pay downpayment $\delta p_{ma}(\Phi)$ in the current period. The value function of a renter is given by

$$
\begin{aligned}
V^R(m^*, s; m, a, k, h = 0; \Phi) \; = & \qquad\qquad (1.3.5) \\
\max_{\{\text{own,rent}\}} \Bigg\{ \max_{k' \geq 0} \Bigg\{ & \ln\left[w_{msa}(\Phi) - r_{ma}(\Phi) - \delta p_{ma}(\Phi) - k' + (1 + i^k)k\right] \\
& + \beta \mathrm{E}\left[V^O(m^*, s; m, a+1, k', 1; \Phi')\right] \Bigg\}, \\
\max_{k' \geq 0} \Bigg\{ & \ln\left[w_{msa}(\Phi) - r_{ma}(\Phi) - k' + (1 + i^k)k\right] \\
& + \beta \mathrm{E}\left[V^R(m^*, s; m, a+1, k', 0; \Phi')\right] \Bigg\}\Bigg\},
\end{aligned}
$$

where the expectation is over the distribution of population next period, $\Phi'$. However, in a stationary economy the distribution is time-invariant, and a rational agent is aware of this.

An owner in period $2 \leq a < T$ decides on savings, and whether to keep the house or sell it and become a renter, taking wages and housing prices as given. Here the tradeoff is between a higher expected future utility $\mathrm{E}\left[V^O\right]$ and a higher current consumption financed by revenues from selling the house. Note that, if the mortgage has not been repaid, then the owner who sells only receives the fraction of the value of the house that

[27] The model, however, can accommodate cross-city differences in age-income profiles. Using Spanish administrative data, De la Roca and Puga (2016) document that larger cities have steeper income profiles.

she has paid for: $p_{ma}(\Phi)(h\mu + \delta)$. The owner's value function is given by

$$\begin{aligned} V^O(m^*, s; m, a, k, h; \Phi) \; = & \qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad (1.3.6) \\ \max_{\{\text{own,rent}\}} \Bigg\{ \max_{k' \geq 0} \Bigg\{ & \ln\left[w_{msa}(\Phi) - \mathbb{I}_{h\leq\kappa}(1+i^h)\mu p_{m,a-h} - k' + (1+i^k)k\right] \\ & + \gamma + \beta \mathrm{E}\left[V^O(m^*, s; m, a+1, k', h+1; \Phi')\right] \Bigg\}, \\ \max_{k' \geq 0} \Bigg\{ & \ln\left[w_{msa}(\Phi) - \mathbb{I}_{h\leq\kappa}(1+i^h)\mu p_{m,a-h} + p_{ma}(\Phi)\min\{h\mu+\delta, 1\} - k' + (1+i^k)k\right] \\ & + \gamma + \beta \mathrm{E}\left[V^R(m^*, s; m, a+1, k', 0; \Phi')\right] \Bigg\}\Bigg\}. \end{aligned}$$

In the last period, the value functions are equal to the current value of consumption. For a renter it is equal to

$$V^R(m^*, s; m, T, k, 0; \Phi) = \ln\left[w_{msa}(\Phi) - r_{ma}(\Phi) + (1+i^k)k\right],$$

and for an owner it is given by

$$\begin{aligned} V^O(m^*, s; m, T, k, h; \Phi) = \ln\big[& w_{msa}(\Phi) - \mathbb{I}_{h\leq\kappa}(1+i^h)\mu p_{m,a-h} \\ & + p_{ma}(\Phi)\min\{h\mu+\delta, 1\} + (1+i^k)k\big] + \gamma. \end{aligned}$$

The expected lifetime utility of an $s$-skilled worker born in location $m^*$ who decides to spend life in location $m$ is

$$V(m|m^*, s, \varepsilon) = V^R(m^*, s; m, a=1, k=0, h=0; \Phi') + \varepsilon(m) - \mathbb{I}_{m\neq m^*}\xi,$$

and the optimal location choice of this worker satisfies

$$m = \operatorname*{argmax}_{m' \in \mathcal{M}} \{V(m'|m^*, s, \varepsilon)\}.$$

### 1.3.3 Political Economy of Housing Supply Regulation

I assume that housing supply regulation determines the elasticity of house prices and rents with respect to demand. Recall from Section 2.2.1 that the elasticity is given by $\frac{1}{\zeta_m - 1}$. I assume that $\zeta_m \equiv \bar{\zeta} + \zeta_m^{\text{reg}} + 1$, where $\bar{\zeta}$ is a common elasticity parameter and $\zeta_{mt}^{\text{reg}}$ is city-specific stringency of housing supply regulation in city $m$. More stringent regulation makes supply less elastic and leads to higher prices in city $m$, as illustrated by the equilibrium price and rent expressions (equations 2.2.10 and 1.3.4).[28]

The level of regulation is determined via a model of probabilistic voting with lobbying (Lindbeck and Weibull (1987), Baron (1994)).[29] In every city there is a regulatory board, and every period there is an election of local government which appoints members of the

[28]In reality different types of regulation may affect supply and prices though different channels. Yet Mayer and Somerville (2000) find that uncertainty associated with obtaining zoning approvals and building permits constrains new development much more than other types of regulation, such as development and impact fees. Paciorek (2013) finds a strong effect of regulation on the supply elasticity.

[29]The model of probabilistic voting with lobbying is described in Persson and Tabellini (2002).

board.[30] Two parties, $A$ and $B$, run for the government and propose a single policy: level of residential land use regulation. The only objective of a party is to be elected and, if elected, they must commit to the proposed level. At the end of each period, all residents aged $a \in \{1, ..., T-1\}$ vote, and the level proposed by the winning party is effective next period.[31] Residents have two considerations when deciding which party to vote for: the expected utility of the proposed regulation level and their idiosyncratic taste for each party.

1. *Expected utility of regulation.* If party $l \in \{A, B\}$ is elected, a worker in state $x = (m^*, s; m, a, k, h)$ will optimally choose to be in state $x'(\zeta_l^{\text{reg}}) = (m^*, s; m, a+1, k_l', h_l')$ next period. In addition, the worker knows that if city $m$ chooses a different level of regulation, the distribution of population in the economy will change to $\Phi_l'$ leading to adjustments in wages and housing prices.

2. *Ideology.* Worker $i$ with ownership status $j \in \{R, O\}$ has an idiosyncratic taste for party $A$, which can be interpreted as ideological bias. This taste shock is denoted by $\sigma_i^j$ and distributed uniformly across workers on $[-1/2\phi_m^j, 1/2\phi_m^j]$. Parameter $\phi_m^j$ essentially measures how consolidated opinions on regulation are among the members of group $j$. In the extreme case of $\phi_m^j \to \infty$, all individuals of group $j$ in city $m$ have the same preference for regulation. In the opposite case of $\phi_m^j = 0$, individuals within the group completely disagree.

In this model, owners prefer a higher level of regulation, since it raises the values of their houses. Renters favor a lower level, since it reduces rents. It also decreases house prices and thus makes downpayment more affordable.

Local elections are financed via campaign contributions. Party $l \in \{A, B\}$ receives $C_l$ from each homeowner who votes for it.[32] The contributions are needed to enact the level of regulation proposed by the party, and their size depends on the proposed level:[33]

$$C_l = \omega_0 \left(\zeta_l^{\text{reg}}\right)^{\omega_1}.$$

The contributions enter the budget constraints and become a part of homeowner's expenses. Taking into account all factors that influence a vote, an individual $i$ with ownership status $j \in \{R, O\}$ votes for party $A$ if

$$V^j\left(x'(\zeta_A^{\text{reg}}); \Phi'(\zeta_A^{\text{reg}})\right) + \sigma_i^j - \mathbb{I}_{j=O} C(\zeta_A^{\text{reg}}) \geq V^j\left(x'(\zeta_B^{\text{reg}}); \Phi'(\zeta_B^{\text{reg}})\right) - \mathbb{I}_{j=O} C(\zeta_B^{\text{reg}}),$$

and for party $B$ otherwise.[34]

[30] In the U.S., municipalities have a Planning and Zoning Commission charged with city planning and recommending to the local government boundaries of zoning districts and regulations to be enforced therein.

[31] I prohibit voting by the oldest generation, since they will not be around next period to live with the results of the vote and hence will be indifferent between the two levels of regulation.

[32] Alternatively, renters could be allowed to contribute toward less regulation. However, this would incite owners to contribute even more and lead to a contributions "arms race". As a result, the equilibrium level of regulation would be the same, but aggregate spending on elections would be much larger.

[33] This approach is close in spirit to Glaeser, Gyourko and Saks (2005a), where homeowners spend time out of work to affect the decisions of the zoning authority, and to Hilber and Robert-Nicoud (2013), where regulation is a function of monetary contributions from landowners and developers to the planning board.

[34] The future distribution of votes in a city also influences the value of locating in the city. However it is completely described by the value functions and the future distribution of labor $\Phi'(\zeta_l^{\text{reg}})$, and thus does not have to enter the value functions separately.

In the unique Nash equilibrium, electoral competition between the two parties makes them converge to announcing the same policy. The equilibrium level of regulation maximizes the weighted social welfare of local residents, where the weights depend on population shares and on how consolidated a group of voters is in its preferences for the policy. The weighted social welfare function is given by

$$W_m(\zeta^{\text{reg}}) = \phi_m^O \int \frac{N_m^O(x)}{N_m} \left(V^O\left(x'(\zeta^{\text{reg}}), \Phi'(\zeta^{\text{reg}}); x\right) - \mathbb{I}_{j=O} C(\zeta^{\text{reg}})\right) dx + \phi_m^R \int \frac{N_m^R(x)}{N_m} V^R\left(x'(\zeta^{\text{reg}}), \Phi'(\zeta^{\text{reg}}); x\right) dx, \quad (1.3.7)$$

where $V^j(x'(\zeta^{\text{reg}}), \Phi'(\zeta^{\text{reg}}); x)$ stands for the next-period value function of a worker currently in state $x$ if the chosen level of regulation is $\zeta^{\text{reg}}$. The integration is performed across all residents of age $a \in \{1, ..., T-1\}$. The elected level of regulation is then

$$\zeta_m^{\text{reg}} = \underset{\zeta^{\text{reg}} \in \mathbb{R}_+}{\operatorname{argmax}} \left\{W_m(\zeta^{\text{reg}})\right\}. \quad (1.3.8)$$

From equation (1.3.7) one can see that the less owners or renters differ in their idiosyncratic preference for regulation, the more weight they have in the social welfare function, and hence more influence on the regulatory board. On the other hand, when the idiosyncratic views of owners or renters on regulation vary a lot, they tend to vote more often in ways that are not determined by regulation. As a result, they have a smaller weight in the welfare function.

Homeowners benefit from a higher $\zeta_m^{\text{reg}}$ since it makes the value of their house higher.[35] Fischel (2001) describes reasons why homeowners might want stricter residential land use regulation, but argues that most of the restrictions capitalize into higher house values. In practice this makes it difficult to distinguish the actions of owners that are explicitly driven by their willingness to increase or maintain the house value from those that are aimed at improving local public services, controlling congestion, etc. At the same time, a model in which the main reason why owners prefer regulation is because it raises house values, such as the model in this paper, can be interpreted more generally, since this motivation contains many other reasons for preferring stringent regulation.[36] For instance, regulation discourages inflows of workers, who would start as renters and vote for less regulation thus harming owners. This can be interpreted as the dislike of congestion, even though congestion is not modeled explicitly.

### 1.3.4 Equilibrium

**Distribution of labor across locations.** The vector of utility shocks $\varepsilon$ follows the extreme value type 1 distribution with parameters $\mu_\varepsilon$ and $\sigma_\varepsilon$ and that the shocks have zero mean.[37] Consider a worker born in location $m^*$ with skill $s$. Before the vector of

[35] An increase in regulation may actually reduce prices if the resulting outflow of labor to other locations is large, as in Chatterjee and Eyigungor (2015). In this paper, the outflows are small due to individual location preferences and the inability to move after the first period.

[36] Dubin, Kiewiet and Noussair (1992) show that in a 1988 election in San Diego, precincts with a larger fraction of owners had a larger proportion of votes cast in favor of growth control measures.

[37] The extreme value type 1 distribution is commonly used in the discrete-choice literature. The density of the extreme value type 1 distribution with parameters $\mu_\varepsilon$ and $\sigma_\varepsilon$ is $f(x) = \exp(-\exp(-(x-\mu_\varepsilon)/\sigma_\varepsilon))$. The mean is $\mu_\varepsilon + \sigma_\varepsilon\bar{\gamma}$, where $\bar{\gamma} \approx 0.5772$ is the Euler-Mascheroni constant, and the variance is $\sigma_\varepsilon^2\pi^2/6$. Hence the utility shock has zero mean if $\mu_\varepsilon = -\sigma_\varepsilon\bar{\gamma}$.

utility shocks $\varepsilon$ is known to the worker, her value of choosing to spend life in location $m'$ is[38]

$$\tilde{V}(m'|m^*, s) \equiv V^R(m^*, s; m', a=1, k=0, h=0; \Phi').$$

Let $\Pi(m|s, m^*)$ be a conditional choice probability (CCP), the probability that, after observing $\varepsilon$, an $s$-skilled worker born in location $m^*$ will choose to live in $m$. The distributional assumption on $\varepsilon$ allows to derive a closed-form expression for the CCP:[39]

$$\Pi(m|m^*) = \frac{\exp\left(\tilde{V}(m|m^*, s)\right)^{\frac{1}{\sigma_\varepsilon}}}{\sum_{m' \in \mathcal{M}} \exp\left(\tilde{V}(m'|m^*, s)\right)^{\frac{1}{\sigma_\varepsilon}}} \tag{1.3.9}$$

Since migration is only allowed once in lifetime, the CCPs translate directly into the city size distribution. The equilibrium supply of age-1 $s$-skilled workers in location $m$ is given by

$$N_{ms1} = \sum_{m^* \in \mathcal{M}} \Pi(m|m^*, s)\psi_{m^*}\lambda(s),$$

where $\psi_{m^*}$ is the exogenous measure of individuals born in $m^*$ and $\lambda(s)$ is the exogenous fraction of $s$-skilled workers. Then the total supply of $s$-skilled workers is $N_{ms} = TN_{ms1}$, and the total population in the location is $N_m = N_{mL} + N_{mH}$.

**Definition 1.3.1.** A *stationary spatial equilibrium* consists of value functions $V^O$ and $V^R$, and the associated decision rules that determine optimal location, ownership status, and savings; prices $w_{msa}(\Phi)$, $p_m(\Phi)$ and $r_m(\Phi)$; new construction of each type in each city, $q_m^j$; levels of regulation $\zeta_m^{\text{reg}}$; conditional choice probabilities $\Pi$; distribution of labor $\Phi$; and a transition function $F : \mathcal{X} \to \mathcal{X}$, such that: (1) the value functions maximize expected utility and the decision rules attain the value functions; (2) wages, house prices and rents clear markets at the city level; (3) the resource constraint holds (aggregate output equals aggregate consumption plus construction costs); (4) the social welfare function (1.3.7) is maximized in every city via the probabilistic voting mechanism; (5) the distribution of labor is stationary: $F(\Phi) = \Phi$.

**Computing an equilibrium.** An advantage of focusing on stationary equilibria is that rational agents learn that they are in a stationary environment and know that next period the distribution of workers across individual states will be the same as in the current period. Moreover, in a stationary equilibrium political parties run with the same proposed level of regulation every period. They know that the composition of population in the city is exactly the same as in the previous period, and therefore the announced level of regulation that maximizes their probability of winning is the same as one period before. Workers, in turn, know that the parties will offer the same level of regulation next period and embed this knowledge in their value functions. These features greatly simplify the computation.

However, even in a stationary environment, the political economy part of the equilibrium poses a significant computational challenge for two reasons. First, maximization of the social welfare function (equation 1.3.7) requires evaluation of workers' value functions at different non-equilibrium regulation levels. To do that, I need to know an entire

[38] In the discrete-choice literature these functions are called *conditional value functions*.

[39] The possibility of obtaining closed-form solutions for conditional choice probabilities in models with extreme value type 1 shocks was first discovered by McFadden (1973).

dynamic path of regulation in every city starting from any level of regulation. Second, when voting on regulation, individuals must know how every elected level of regulation would affect labor supply in a city. In other words, they must fully know the shape of the aggregate transition function $F$. Yet $F$ is a high-dimensional object and its computation is difficult. In order to deal with these two issues during computation of an equilibrium, I make two simplifying assumptions. In Appendix A.1, I discuss these assumptions and other details of the computation of a stationary spatial equilibrium.

### 1.3.5 Rise in Regulation, Skill Sorting and Wage Inequality

Why has regulation increased since the 1970s? Glaeser, Gyourko and Saks (2005a) examine several possibilities and assert that the most likely reasons are that residents' groups have become more politically influential, either building upon the organizational successes of the civil-rights and the anti-war movements or because of better education of homeowners. Another possible reason is that that the ability of developers to affect decisions of local planning boards using legal and illegal payments has diminished thanks to the overall reduction in corruption and improvements in the news media. Fischel (2001) claims that homeowners would support any measure that raises the value of their property, strict land use regulation being one of them, and since the 1970s they have been more able to incite local governments to adopt regulation that favors their interests. According to Fischel (2015), one reason why regulation has risen is suburbanization. First, suburban communities tend to be more demographically homogeneous than central cities, which makes it easier for residents to organize and push for their desired policies. Second, large employers, who might support new residential construction, typically have smaller presence, and therefore less influence, in predominantly residential suburban communities. Another reason is the growing importance of house values in the portfolios of homeowners, which made them more willing to undertake actions that preserve or increase the values of their houses.

The political economy model of regulation proposed in this paper can accommodate all these forces. The rise in homeowners' influence, either because of greater political power or suburbanization, can be modeled as an increase in the degree of consolidation of owners' opinions on regulation, $\phi_m^O$. Even though in the model developers do not take part in local politics, the decline in their influence can still be modeled as an increase in the size of $\phi_m^O$ relative to $\phi_m^R$, since the interests of developers would be aligned with those of renters. Finally, if real prices increase, housing becomes a more important part of households' portfolios, and therefore value functions will be more sensitive to price changes. As a result, all else equal, the rate of change of $V^O$ with respect to regulation will be higher for a given level of $\zeta^{\text{reg}}$ and raise the value of the argument that maximizes the social welfare function.[40]

In the model, changes in regulation occur in response to changes in fundamentals, such as exogenous type-specific productivities. Suppose that city $m$ experiences a proportionate growth of type-specific productivities $g_{msa}$. This attracts new labor to the city, and demand for housing goes up. As a consequence, prices increase and labor inflow slows down. However, the inflow of high-skilled workers is not affected as much as the inflow of the low-skilled, since the former earn higher wages and therefore spend a smaller share of

[40]The rate of change of $V^R$ for a given level of $\zeta^{\text{reg}}$ will be larger too. But in the data there are more owners than renters and calibrated $\phi_m^O$ is larger than $\phi_m^R$, hence the increase in the sensitivity of $V^O$ will be quantitatively more important than the increase in the sensitivity of $V^O$.

income on housing. As a result, the share of high-skilled workers in the city grows. If, for any reason, cities with initially high fraction of skilled labor experience faster productivity growth, then skill sorting ensues, i.e. locations with initially high share of high-skilled workers attract a larger number of the high-skilled than other locations. As a result, the differences in mean wages go up.[41]

What role does regulation play? When, following an inflow of labor, house prices go up, real estate becomes more important in individual portfolios, and owners vote to increase the level of regulation. This raises prices even more, and makes the relative inflow of low-skilled workers even lower. Skill sorting is more intense and wage inequality grows by more. In other words, the endogenous regulation mechanism *amplifies* the effect of increasing differences in exogenous productivities on skill sorting, house price dispersion, and wage inequality across locations. If productivity growth is skill-biased, i.e. $g_{mHa}$ grows faster than $g_{mLa}$, then the magnitude of these effects is even larger.

## 1.4 Parameter Values

The quantitative model has 190 locations, which correspond to the 190 metro areas in my sample (see Section 1.2.1). Parameters of the model are set to reproduce central facts about local labor and housing markets, migration, and residential land use regulation in the United States in the 2005-2007 period. I focus on these years, since the data on regulation is only available for the year 2007. I take several parameters from the literature or calibrate them outside the model. Then I estimate the labor demand equation to obtain the exogenous type-scecific productivities and the elasticity of substitution between skills. Next I estimate the housing supply equation to obtain the elasticities of housing prices with respect to population density and regulation. The remaining parameters are calibrated jointly within the model. The rest of the section describes the details. Parameter values are summarized in Table 1.3.

### 1.4.1 Labor Markets

In the model, wage differences across locations are largely determined by exogenous location-skill-age specific productivities. I estimate the productivities for every year $t$ using the labor demand equation which, after taking log of equation (1.3.2), can be expressed as

$$\ln w_{msa,t} = \ln\left((1-\alpha)\left(\frac{\alpha}{i^k}\right)^{\frac{\alpha}{1-\alpha}}\right)+\frac{1-\eta}{\eta}\ln\left(1+\left(\frac{\sum_{\tilde{a}=1}^{T} g_{ms'\tilde{a},t}N_{ms'\tilde{a},t}}{\sum_{\tilde{a}=1}^{T} g_{ms\tilde{a},t}N_{ms\tilde{a},t}}\right)^{\eta}\right)+\varphi_t+\ln g_{msa,t}, \tag{1.4.1}$$

where $\varphi_t$ is the year fixed effect. The interest rate is set to $i^k = \frac{1}{\beta} - 1 = \frac{1}{0.96} - 1$. The share of capital $\alpha$ is 0.335, following Valentinyi and Herrendorf (2008).

The remaining labor market parameters are estimated from the labor supply equation. If we were to estimate the equation (1.4.1), the type-specific productivity parameters $\ln g_{msa,t}$ would be regression residuals. However, these residuals are correlated with the regressor. First, mechanically, by being a part of labor supply in efficiency units. Second, the type-specific productivities are likely to be correlated with raw labor supply through

[41] That the increase in skill sorting leads to the increase in mean wage differences cannot be shown analytically. However, for the model parameters and the observed changes in skill shares, this is the case.

channels other than wages. One possibility is that the size and the skill mix of labor force affect the productivity shifters via agglomeration externalities.

The second endogeneity problem can be overcome by using the Bartik (1991) labor demand shocks as an instrument for labor supply $N_{msa}$. Bartik shocks have been extensively used for identification in labor and urban economics, and are obtained by interacting cross-MSA differences in industrial composition at time $t$ with changes in industrial composition at the national level between $t-1$ and $t$. The identifying assumption is that changes in industrial composition in all cities but $m$ are uncorrelated with labor supply shocks in $m$. The Bartik instrument is defined as the change in labor supply of type $(s, a)$ in city $m$ as predicted by changes in the supply of this type of labor in each of the industries $z \in \mathcal{Z}$ in the rest of the economy:

$$B_{msa,t} = \sum_{z \in \mathcal{Z}} \left( \ln \left( \sum_{m' \neq m} N_{zm'sa,t} \right) - \ln \left( \sum_{m' \neq m} N_{zm'sa,t-1} \right) \right) \frac{N_{zmsa,t-1}}{N_{msa,t-1}}.$$

In order to construct the Bartik instruments, I use 13 industry groups in the Census classification.[42] Since the instrument depends on industrial composition of city $m$ in $t-1$ and the change in labor supply to each industry in all cities but $m$, it is exogenous to current productivity levels in city $m$. The predicted supply of labor of each type is $\ln \hat{N}_{msa,t} = \ln N_{msa,t-1} + B_{msa,t}$, and the instrumented labor demand is given by

$$\ln w_{msa,t} = \ln \text{const}(\alpha, i^k) + \frac{1-\eta}{\eta} \ln \left( 1 + \left( \frac{\sum_{\tilde{a}=1}^{T} g_{ms'\tilde{a},t} \hat{N}_{ms'\tilde{a},t}}{\sum_{\tilde{a}=1}^{T} g_{ms\tilde{a},t} \hat{N}_{ms\tilde{a},t}} \right)^{\eta} \right) + \varphi_t + \ln g_{msa,t}. \tag{1.4.2}$$

The Bartik approach cannot however solve the first endogeneity problem, i.e. that type-specific productivities enter one of the regressors. Moreover, the definition of the Bartik shock requires a previous period. This implies that I cannot use 1980 and must start my analysis from 1990, missing a decade in which important changes in regulation and distribution of economic activity across space happened.[43]

Therefore I proceed with estimating the original labor demand equation (1.4.1). I argue that the consequences of the endogeneity are quantitatively small. First, using Bartik shocks for the period of 1990-2007 yields similar parameter estimates as the estimation that ignores endogeneity. The elasticity parameter is $\eta = 0.626$ when estimated from equation (1.4.2) and $\eta = 0.644$ when estimated from (1.4.1) using the 1990-2007 data. The mean and the standard deviation of the vector $g$ are 16.84 and 6.70 when estimated from (1.4.2), and 17.34 and 6.92 when estimated from (1.4.1). The correlation between $g$ produced by estimation with and without Bartik shocks is 0.99, which means that the estimates obtained from (1.4.1) are simply slightly shifted upwards, but the relative values of $g$ are nearly identical. Second, even though the productivity parameters $g$ are correlated with one of the regressors by construction, the correlation is only -0.05, thus the endogeneity bias is small.

[42]The industry groups are: (1) agriculture, forestry, and fisheries; (2) mining; (3) construction; (4) manufacturing of nondurable goods; (5) manufacturing of durable goods; (6) transportation, communications, and other public utilities; (7) wholesale trade; (8) retail trade; (9) finance, insurance, and real estate; (10) business and repair services; (11) personal services; (12) entertainment and recreation activities; (13) professional and related services.

[43]While I could use the data from 1970 to define a Bartik shock for 1980, the IPUMS version of the Census only identifies 119 metropolitan areas for 1970.

The labor demand equation is estimated using data from 1980, 1990, 2000 Censuses and 2005-2007 three-year American Community Survey sample. The estimated $\eta$ is equal to 0.6824 and is close to the range of values estimated in Card (2009).[44]

### 1.4.2 Housing Markets

The parameters that characterize the mortgage facility are fixed using the existing data on mortgages. According to the American Housing Survey in 2013, the average downpayment rate was 16.1% (excluding homes bought outright) and 25.1% (including homes bought outright). In practice, a common downpayment in mortgage contracts is 20%. Hence I set $\delta = 0.2$. As much as 80% of outstanding mortgages had a 30-year period, thus the mortgage term in the model is set to $\kappa = 6$ periods, which corresponds to 30 years. As a result, the per-period mortgage payment is $\mu = (1 - 0.2)/6 = 0.1333$. Finally, the interest rate on the mortgage is $i^h = 0.0621$, the average rate in 2005-2007, as reported by Freddie Mac.[45]

The remaining housing supply parameters are estimated using the equilibrium price and rent expressions. Taking logs of equations (2.2.10) and (1.3.4), and using $\zeta_m = \bar{\zeta} + \zeta_m^{\text{reg}} + 1$, we obtain the expression for the house price

$$\ln p_m = \ln \chi_m^O + \ln\left(\bar{\zeta} + \zeta_m^{\text{reg}} + 1\right) + \left(\bar{\zeta} + \zeta_m^{\text{reg}}\right) \ln\left(\frac{N_m}{\Lambda_m}\right), \tag{1.4.3}$$

and the rent

$$\ln r_m = \ln(1-\rho) + \ln \chi_m^R + \ln\left(\bar{\zeta} + \zeta_m^{\text{reg}} + 1\right) + \left(\bar{\zeta} + \zeta_m^{\text{reg}}\right) \ln\left(\frac{N_m}{\Lambda_m}\right). \tag{1.4.4}$$

Since the land use regulation data is only available for 2007, housing supply is estimated using individual-level data from the 2005-2007 ACS three-year sample. Define $p_{mi}^j = p_{mi}$ if $j = O$, and $p_{mi}^j = r_{mi}$ if $j = R$. Rents $p_{mi}^R$, originally reported at monthly frequency, are converted to 5-year rates to be consistent with the quantitative model. Combining equations (1.4.3) and (1.4.4), we can express the price of unit $i$ as

$$\ln p_{mi}^j = \mathbb{I}_{j=R} \ln(1-\rho) + \ln \chi_m^j + \ln\left(\bar{\zeta} + \zeta_m^{\text{reg}} + 1\right) + \left(\bar{\zeta} + \zeta_m^{\text{reg}}\right) \ln\left(\frac{N_m}{\Lambda_m}\right) + S_i^j + \epsilon_{mi}^j, \tag{1.4.5}$$

Land endowment $\Lambda_m$ is taken from Saiz (2010) and represents the fraction of territory within a 50km radius from the population centroid of a metropolitan area that is not occupied by water or slopes steeper than 15%.[46] The vector $S_i^j$ controls for differences in quality of units and consists of dummy variables for the number of rooms, the year of construction, and the number of housing units in the structure where the unit is located. Each of the dummies is allowed to vary depending on whether the unit is rental or owner-occupied:

$$S_i^j \equiv S_i^{\text{rooms},j} + S_i^{\text{year},j} + S_i^{\text{units},j}.$$

[44] Using a similar CES production function, Card (2009) estimates that the elasticity of substitution between college-equivalent and high school-equivalent labor in the U.S. is between 1.5 and 2.5, which corresponds to $\eta$ between 0.33 and 0.6.

[45] http://www.freddiemac.com/pmms/pmms30.htm

[46] This implies that potential land area of an MSA only depends on geographic characteristics and not on population size or regulation.

Equation (2.2.8) cannot be estimated directly: since prices affect labor supply, there is reverse causality. This issue is overcome by instrumenting for labor supply using Bartik (1991) labor demand shocks, similar to those described in Section 1.4.1. The Bartik instrument is defined as the change in the supply of labor of type $(s, a)$ with ownership status $j$ in city $m$, as predicted by changes in the supply of this type of labor in each of the industries $z \in \mathcal{Z}$ in the rest of the economy between 2000 and 2007. The instrument is given by

$$B^j_{msa,2007} = \sum_{z\in\mathcal{Z}} \left( \ln\left( \sum_{m'\neq m} N^j_{zm'sa,2007} \right) - \ln\left( \sum_{m'\neq m} N^j_{zm'sa,2000} \right) \right) \frac{N^j_{zmsa,2000}}{N^j_{msa,2000}},$$

and the predicted supply of labor of each type is $\ln \hat{N}^j_{msa} = \ln N^j_{msa,2000} + B^j_{msa,2007}$.

To convert the Wharton index of regulation into units suitable for the housing supply specification in this paper, I decompose the regulation level as

$$\zeta^{\text{reg}}_m = \tilde{\zeta}^{\text{reg}} \tilde{W}_m, \tag{1.4.6}$$

and estimate $\tilde{\zeta}^{\text{reg}}$. $\tilde{W}_m$ is the log of the Wharton index plus 3.[47] The equation (2.2.8) can be transformed into the following estimating equation

$$\ln p^j_{mi} = \text{const} + \bar{\zeta} \ln\left(\frac{\hat{N}_m}{\Lambda_m}\right) + \tilde{\zeta}^{\text{reg}} \tilde{W}_m \ln\left(\frac{\hat{N}_m}{\Lambda_m}\right) + S^j_{mi} + \varphi_m + \epsilon^j_{mi}, \tag{1.4.7}$$

where $\varphi_m$ is the city fixed effect and $\hat{N}_m = \sum_{j\in\{O,R\}} \sum_{s\in\{H,L\}} \sum_{a=1}^{T} \hat{N}^j_{msa}$. I identify $\bar{\zeta}$ and $\tilde{\zeta}^{\text{reg}}$ from the housing supply equation. The estimated elasticities are: $\bar{\zeta} = 0.1093$ and $\tilde{\zeta}^{\text{reg}} = 0.0666$. Using the estimated $\tilde{\zeta}^{\text{reg}}$, I construct the measure of regulation based on equation (1.4.6) and use moments of the distribution of $\zeta^{\text{reg}}$ in the calibration of the model (see Section 1.4.4).

Finally, I calibrate $\chi^j_m$. First, I assume that $\chi^O_m = \chi^O$ in all cities and fix $\chi^O$ so as to match the average expenditures on housing as a fraction of wage and salary income.[48] According to the Consumer Expenditure Survey, this fraction was 0.199 in 2007.[49] Then $(1-\rho)\chi^R_m = \frac{p_m}{r_m}\chi^O_m$, i.e. $(1-\rho)\chi^R_m$ is found from the observed price-to-rent ratio in every location in 2007 using the model of the construction sector. Note that I cannot separately identify $\rho$ and $\chi^R_m$, however this is not needed for the quantitative model.

### 1.4.3 Workers, Preferences and Location Choice

There are 8 model periods that correspond to ages 25-29, 30-34, ..., 60-64. The fraction of high-skilled workers in the economy is $\lambda_H = 0.3984$, which is the share of observations with a college degree in the sample. The time discount factor is $\beta = 0.96$.

[47] The original Wharton Index is built such that it has mean of zero and standard deviation of one. This transformation is used by Saiz (2010) in order to ensure positive levels of regulation in the estimation. He claims that adding other positive constants to the log of the original index does not change his results.

[48] While physical construction costs do differ across cities, Gyourko and Saiz (2006) show that most of the differences come from factors that in my model are captured by the inverse supply elasticity, land availability and population density, and not by physical construction costs $\chi^j_m$.

[49] It is lower than the 0.24 share computed by Davis and Ortalo-Magné (2011). The difference arises because they use rent including utilities. I instead use both rent and mortgage payments, but exclude utilities, since they are unlikely to vary across locations for the same reasons prices vary in my model.

The remaining parameters related to workers and their preferences are calibrated (all values and targets are summarized in Table 1.3). The utility of homeownership $\gamma$ affects how often individuals choose to own rather than rent, and thus is calibrated to match the average homeownership rate in the U.S.

The disutility of living outside the home location, $\xi$, determines the relative importance of economic factors, such as housing prices and wages, in location choices. The value of $\xi$ is important for quantitative exercises with counterfactual levels of regulation. If $\xi$ is high enough, then changes in regulation will have no effect on the economy, since all individuals live in their birth locations no matter what. If $\xi = 0$, then the distribution of population and economic activity is extremely sensitive to changes in regulation. The value of $\xi$ must reflect the propensity of the young to migrate, and therefore is calibrated to replicate the five-year inter-MSA migration of the 20-29 year olds. Unfortunately, five-year migration is not observed directly. Hence I construct the five-year rates using the metro area of residence one year ago reported by individuals in the ACS. If an individual of age 20-29 reports an MSA different from the MSA of current residence, he or she is a migrant. I calculate the five-year rate directly from the one-year rate as $mig_5 = 1 - (1 - mig_1)^5$, and obtain 0.361, i.e. more than one-third of individuals aged 20-29 move across metropolitan areas in a five-year period.

Since migration is impeded by home attachment, the distribution of the newborn population $\psi_m$ determines the city size distribution in the model. I calibrate $\psi_m$ by targeting the observed distribution of labor force across metro areas in 2005-2007.[50] Finally, the variance of the location preference shocks $\varepsilon$ cannot be identified within the model, and I assume that the parameter that governs the variance, $\sigma_\varepsilon$, is equal to 1.[51]

### 1.4.4 Regulation

The influence of renters on the local government, $\phi_m^R$, is assumed to be the same in all locations and is normalized to 1. The influence of owners is parameterized as a function of the fraction of college-educated individuals among homeowners in city $m$:

$$\phi_m^O = \bar{\phi}^O \frac{N_{mH}^O}{N_m^O}. \tag{1.4.8}$$

The assumption that $\phi_m^O$ depends on the fraction of college graduates relies on the assertion by Glaeser, Gyourko and Saks (2005a) that owners might have become more politically organized as education levels have increased. For instance, highly educated workers may have a better ability to unite for a common goal or have a better understanding that, by organizing their efforts, they have higher chances to persuade local government to serve to their needs.[52] Alternatively, college educated residents may have stronger preferences for regulation in order to avoid congestion or preserve current appearance of their city.

[50] Many spatial models use unobserved amenities to reproduce the observed distribution of population, Hsieh and Moretti (2015) being one example. Hence, even though there are no amenities in this model, they could be introduced to play the same role as $\psi_m$.

[51] Most papers in the migration literature that use extreme value type 1 shocks cannot identify the variance parameter and normalize it to unity. The reason is that, since CCPs are defined relative to each other, $\sigma_\varepsilon$ simply rescales all other parameters. See Arcidiacono and Ellickson (2011) for discussion.

[52] Baldassare and Protash (1982) estimate that the best predictor of anti-growth policies among North California city planning agencies is the share of population employed in white-collar jobs. DiPascuale and Glaeser (1999) find that homeowners are more likely to vote in local elections.

Indeed, I find that college share has a significant positive effect on a metro area's Local Political Pressure Index even after controlling for wages, house prices, land availability and the share of voters who supported a democratic candidate in 2008 presidential elections (Table 1.2).[53] In a similar regression where the WRLURI is the dependent variable, the effect of college is small and insignificant, which suggests that in MSAs with more college graduates homeowners have more influence on local governments even if it does not necessarily result in more stringent regulation. The predictions of the model are identical – higher $\phi_m^O$ due to larger proportion of college graduates increases the influence of owners but does not guarantee higher regulation, since other factors also play a role.

The parameter $\bar{\phi}^O$ is calibrated to match the standard deviation of the estimated regulation $\zeta_m^{\text{reg}}$. The parameters of the campaign contribution function, $\omega_0$ and $\omega_1$ are set as follows. Since $\omega_0$ determines the magnitude of the contributions, its target is the average regulation. At the same time, $\omega_1$ affects how compressed the distribution of regulation is, hence the target for this parameter is the p75-p50 ratio of the distribution of regulation. Since the observed distribution of regulation is asymmetric, the p75-p50 ratio can be used on top of the standard deviation to identify an additional parameter. In the quantitative model, campaign contributions are equal to 1.7% of labor income, hence the fact that they are not used anywhere else in the economy should not have tangible general equilibrium consequences. All parameter values and targets are summarized in Table 1.3.

## 1.5 Benchmark Economy

This section discusses the benchmark economy calibrated to the U.S. economy in 2005-2007 (see Section 1.4). Table 1.4 compares the empirical targets for the calibrated parameters and the corresponding moments produced by the model. The calibrated model reproduces very well the six targeted moments, and the distribution of population is nearly perfectly correlated with the one observed in the data. The model also comes fairly close to reproducing a set of non-targeted moments (Table 1.5). Importantly, even though I assume that individuals of all types consume the same amount of housing, the model reproduces almost exactly the skill differences in expenses on housing and homeownership rates, even though these moments are not targeted. At the same time, the model underpredicts the magnitude of the dispersion of house prices across MSAs. One important reason for this is that in the model only contemporary factors determine the prices. In reality the expectations of future price growth are likely to be an important factor behind high prices in cities like New York and San Francisco.

Most importantly, the model produces a fairly accurate prediction of the level of regulation in each location, even though I only target three moments of the distribution of $\zeta_m^{\text{reg}}$. The correlation between the WRLURI and the regulation predicted by the model is 0.48 (Figure 1.10). However, regulation affects land use and prices through many channels, while the channel emphasized in the model is the elasticity of supply. The correlation between the regulation predicted by the model and the Approval Delay Index (ADI), a part of the Wharton Index most related to the supply elasticity, is 0.68 (Figure 1.11).[54]

[53] The Local Political Pressure Index is one of the subindices of the Wharton Index. It measures the degree of involvement by various local actors, such as community pressure groups, in the development process.

[54] The Approval Delay Index takes into account the average duration of the review of a building permit, the typical amount of time between application for rezoning and issuance of a building permit

Given that many reasons for why regulation differs across locations are outside the scope of the model, these correlations are fairly high.[55] If we interpret these correlations as the $R^2$ in the regressions of the model-predicted regulation on the WRLURI and the ADI, we can say that the model explains 23% of the variation in the WRLURI and 46% of the variation in the ADI.[56]

In addition to being able to replicate aggregate moments and the distribution of regulation, the model is also capable of reproducing other cross-city distributions. Table 1.6 shows that city-specific homeownership rates, house prices, and fractions of labor force with college degree are all highly correlated with their counterparts in the data. The relationship between the observed and predicted house prices and shares of high-skilled workers are also depicted in Figures 1.12 and 1.13, respectively.

Table 1.7 lists the top 10 regulated metro areas in the model and their ranks in the data. It is remarkable, though not surprising, that four out of ten most regulated places in the model are located in California. The state has been known for its strict land use regulation which is often blamed for high housing prices there (Quigley and Raphael, 2005). One notable outlier in the top 10 list is Chicago. In the data, regulation there is fairly low, however the model predicts high regulation since this is an MSA with large population and a sizable proportion of its territory in the 50km radius is occupied by the lake.

### 1.5.1 Static Effects of Regulation

How do levels and cross-city differences in regulation matter for aggregate outcomes, such as output, and distributional outcomes, such as differences in wages and housing prices across locations? In this section, I study responses of the economy to exogenous changes in the distribution of regulation levels. The results are summarized in Table 1.8.

First, I equalize regulation levels in all locations to the population-weighted mean from the benchmark economy (0.0821). Regardless of the average level of regulation, differences across cities may act as distortions and lead to misallocation of labor across space, as in Hsieh and Moretti (2015). I find that setting regulation in all cities to the weighted mean level would result in an 11% decline in average house prices. The reason for this is that in the model prices are a convex function of the level of regulation.[57] Furthermore, equalizing regulation leads to a 68% fall in the variance of log prices. The result is not surprising, since regulation is a key component of construction costs in the model, and is consistent with Glaeser, Gyourko and Saks (2005b) and Saiz (2010), who found that a major part of the variation in housing prices across metro areas in the U.S. can be attributed to differences in residential land use regulation. In addition, equalizing regulation would lead to an approximately 2% increase in output and wages, as well as an 8% drop in the variance of log mean wages.

Second, I set regulation in every city to 1/2 of the calibrated level. In this case, the distortions that arise from differences in regulation are still present, but are half as important everywhere. As a result of this experiment, the variance of log prices falls by

for hypothetical projects, and the typical amount of time between application for sub-division approval and the issuance of a building permit conditional on proper zoning being in place.

[55]Some of the reasons include historical land use patterns (Glaeser and Ward, 2009) and political ideology of local voters (Kahn, 2011).

[56]In a univariate linear regression, $R^2$ is equal to the square of the correlation between the regressor and the dependent variable.

[57]It is straightforward to check from equation (2.2.10) that $\partial^2 p_m/\partial(\zeta_m^{\text{reg}})^2 > 0$

half due to the fact that now construction costs are less dependent on regulation. Output grows by 1.9%. Wages also grow by 1.9% and the variance of log wages across MSAs falls by nearly 10%.

Finally, I set regulation to zero in all cities. Now regulation has no effect on housing prices, and they are determined solely by population density and physical construction costs. As a consequence, the variance of log house prices shrinks to just 15% of the benchmark variance. House prices are low and very similar in all locations, and therefore are relatively unimportant in the location choices of individuals. In this experiment, output and wages grow by 2.4%. Variance of log wages falls to a mere 15% of the benchmark level.

## 1.6 Endogenous Rise of Regulation from 1980 to 2007

What are the implications of the rise in regulation for aggregate productivity, and for wage and house price dispersion across metro areas? A natural way to answer this question would be to construct a counterfactual 2007 economy in which regulation is at the level of 1980. However, regulation is not observed in 1980. Hence I first construct a 1980 economy in which regulation is imputed from the model. To this end, I change the city-, skill-, and age-specific productivities, college attainment, national workforce size and the average mortgage rate to the 1980 level.[58] I also change the physical construction cost of owner-occupied housing $\chi^O$ to 8,935 and the utility of homeownership $\gamma$ to 0.431 in order to match the expenditures on housing and the homeownership rate in 1980.[59] Finally, I recalibrate the distribution of $\psi_m$ in order to reproduce the city size distribution in 1980. The rest of the parameters are left as in the benchmark calibration. In this 1980 economy regulation adjusts endogenously: it becomes smaller on average and less variable across metro areas. Figure 1.14 depicts the distributions of regulation levels in the benchmark and the 1980 calibrations. Table 1.9 displays the fit of a set of moments in the 1980 calibrated model relative to the data.

Then I construct a counterfactual economy in which all technological parameters and skill supply are as in 2007 but regulation is fixed at the 1980 level. The effect of the rise in regulation can be evaluated by comparing the benchmark economy with the same economy in which regulation remains fixed at the 1980 level. The results of this counterfactual experiment are summarized in Table 1.10.

The primary effect of the increase in regulation is the misallocation of labor: as real estate in productive locations becomes prohibitively expensive some workers trade off wages for more affordable housing in less productive places. Figure 1.15 shows that, if regulation had not increased since 1980, large productive metro areas would be even larger. This misallocation reduced aggregate productivity growth. In the absence of changes in regulation, total output would be 2.1% and mean wages 2% higher in 2007 than they actually were. These effects arise because productive areas tend to be more regulated, and therefore have higher house prices. As a result, labor is misallocated, as

[58] The estimated equation (1.4.1) provides productivities for 1980. College attainment is changed from 0.398 in 2007 to 0.255 in 1980. The average mortgage rate was 13.74% in 1980, according to the Freddie Mac data.

[59] Homeownership rate and expenses on housing barely changed between 1980 and 2007. Homeownership rate increased from 0.709 to 0.725. Housing expenses, as a fraction of wage and salary income, grew from 0.192 in 1984 to 0.199 in 2007. The earliest available aggregated data from the Consumer and Expenditure Survey is for 1984, hence I use it as a proxy for 1980.

workers often choose to reside not where they are most productive but where housing is affordable. If there were no changes in regulation since 1980, there would be many more workers in some highly productive areas, and output in cities such as New York and San Diego, would be more than 40% larger (Table 1.11).

The magnitude of skill sorting is measured by the regression coefficient of the change in the fraction of college graduates in a city's labor force between 1980 and 2007 on the fraction in 1980. In the benchmark economy this coefficient is 0.283. However, when regulation is kept at the 1980 level, the coefficient falls to 0.133, i.e. the endogenous regulation mechanism accounts for about 53% of the skill sorting between 1980 and 2007. This difference emerges because fewer low-skilled would have to leave the most productive areas because of being priced out of local real estate markets.

More intense skill sorting leads to higher wage inequality. Indeed I find that if regulation had remained at the 1980 level, the variance of log wages across metro areas would be 0.147, whereas in the benchmark economy it is 0.162. This difference makes up about 0.23 of the rise in the inequality between 1980 and 2007 benchmark economies, hence the increase in regulation accounts for 23% of the growth in wage inequality across MSAs during this period.

However the largest effects of regulation are observed in housing markets. If regulation had not changed since 1980, house prices would still grow due to rising construction costs and population density, but the average price in 2007 would be 43% smaller than in the benchmark economy. Moreover, absent the growth in regulation, the variance of log prices would be only grow from 0.049 to 0.062, compared to 0.141 in the benchmark 2007 economy, i.e. the growth of house price dispersion would be 85% smaller.[60]

The effects of the rise in regulation are heterogeneous across metro areas. If regulation had not changed since 1980, large productive cities would be even larger than they currently are: the population of New York, Los Angeles and Chicago would be 61%, 43% and 73% larger, respectively (Table 1.11). At the same time, most small cities would shrink. Without changes in regulation house prices in New York, Los Angeles, San Francisco and Miami would be more than 60% lower than they are now. At the same time, in inexpensive and lightly regulated areas, such as Dallas and Houston, they would not be much different compared to the present levels.

In this counterfactural experiment the effect on aggregate productivity is modest, compared to the findings of Hsieh and Moretti (2015).[61] This is because workers have strong non-economic preferences for locations: attachment to home and location-specific utility shock. Wages and house price differences are often not large enough to overcome the disutility of living outside the preferred location. Thus even dramatic changes in regulation would have a moderate effect on the distribution of labor across space.

The effects of the increase in regulation are computed using a model in which the productivity of workers does not depend on city size. However, the estimates of agglomeration effects in the literature are not large enough to make a sizable difference for this

[60] Gyourko, Mayer and Sinai (2013), using a different framework in which regulation is exogenous and fixed over time, find that the rise in college supply and the increase in wage inequality can explain more than 80% of growth in house price dispersion between 1970 and 2000.

[61] Hsieh and Moretti (2015) find that reducing regulation in only three highly productive metro areas – New York, San Francisco and San Jose – to the median U.S. level would raise aggregate productivity by almost 10%. They find a much larger effect than the current paper due to the assumption of free mobility of workers. In their model changes in housing supply elasticities lead to a massive reallocation of labor and New York, San Francisco and San Jose become more than five times larger. When they restrict mobility, their results are much smaller.

paper's quantitative results: existing studies find that doubling the city size increases productivity by 4-5%.[62] If anything, a model with agglomeration might produce stronger results than I currently find, since, due to reallocation of workers to already big cities, productivity there would become even higher.

## 1.7 Policy Interventions

In the U.S., the federal and state governments have virtually no authority to interfere with municipal decisions on land use.[63] Land use regulation in the U.S. has always been administered by municipal governments, and direct federal involvement in land use issues would be unconstitutional.[64] In the model in this paper likewise local governments choose regulation independently, only considering local welfare and disregarding possible nationwide effects of their decisions. However, as the exercise in Section 1.6 illustrates, the freedom of cities to set their preferred level of regulation results in lower aggregate productivity. This happens because residents of any given city, when choosing regulation independently, impose an externality on the rest of the economy.

In this section, I study two alternative arrangements that reduce the level of regulation in those locations where homeowners have incentives to impose strict regulation. In the first, cities may choose their level of regulation up to an exogenous upper limit instituted and enforced by a central government. While this policy is not possible to implement due to legal constraints to federal involvement in local land use, it provides a ballpark estimate of what the central government could achieve with such a policy. In the second, the federal government introduces a tax that discourages regulation.

### 1.7.1 Cap on Regulation

Suppose that the federal government sets an upper limit on the level of regulation that no city can exceed. The election mechanism remains as described in Section 1.3.3 but, instead of equation (1.3.8), the chosen level of regulation has to satisfy

$$\zeta_m^{\text{reg}} = \underset{\zeta^{\text{reg}} \in [0, \bar{\zeta}^{\text{reg}}]}{\text{argmax}} \left\{ W_m(\zeta^{\text{reg}}) \right\},$$

where $\bar{\zeta}^{\text{reg}}$ is the exogenously established upper limit.

In the following exercise regulation is capped at $\bar{\zeta}^{\text{reg}} = 0.0821$, the weighted average level of regulation observed in the data. All other parameters are taken from the benchmark economy. The results of the experiment are summarized in Table 1.12.

Introduction of a cap on regulation raises output and wages by 1.4%, as labor reallocates to more productive areas which are too expensive when regulation choices are unrestricted. Under the new regime, wage inequality across metro areas declines by more than 3%. However, the largest effect is on housing markets. On average, prices fall by 19%, and by much more in the most expensive areas: in New York prices drop by 54% and in San Francisco by 46%. The dispersion of house prices across MSAs shrinks to just two-thirds of the level under decentralized regulation. The policy also makes homeownership more widespread: the average ownership rate goes up from 73.4% to 80.6% and

[62] See Ciccone and Hall (1996) and Rosenthal and Strange (2008). Combes and Gobillon (2015) offer a comprehensive up-to-date review of empirical estimates of agglomeration externalities.

[63] Hirt (2014) discusses the history of land use regulation in the U.S. and compares it to other countries.

[64] See Gyourko and Molloy (2015).

the ratio of ownership rates of high to low skilled workers falls from 1.2 to 1.15. In this experiment, the differences in regulation across cities become much smaller. Most cities that were highly regulated in the benchmark economy simply choose $\bar{\zeta}^{\text{reg}}$, the highest possible level of regulation.

### 1.7.2 Taxing Highly Regulated Cities

While the previous policy intervention would be successful in reducing the negative aggregate and distributional effects of regulation, it is politically infeasible due to legal barriers to federal involvement in local land use.

A more realistic way to deal with excessive regulation is to introduce a Pigouvian tax that reduces incentives of local governments to regulate housing supply. This tax can take numerous forms. One option is a national system of transfers between communities in which the size of the transfer depends on a measurable indicator of supply restrictions (e.g. number of constructed units per capita). Another option is to introduce amendments to the personal taxation system. For instance, the federal government could lower the limit for the mortgage interest deduction and use the tax revenues to stimulate construction in highly regulated areas.[65] Also, the federal government could reform taxation of real estate capital gains. Currently, households can deduct up to $500,000 of the taxable profit from the sale of real estate, and the capital gains tax rate does not depend on the sale price.[66] Lowering the deduction limit or making the tax rate increasing in the sale price may reduce incentives of homeowners to introduce supply restrictions that result in higher prices.

All these proposals essentially tax owners of expensive real estate, and thus can be interpreted as a progressive property tax. To understand how successful these policies might be, I introduce a redistributive tax which encourages deregulation of housing supply. Under this tax scheme, homeowners in expensive cities pay higher taxes on the value of their property. The tax proceeds are then transfered to owners in inexpensive places. I assume that the tax rate depends on house prices as follows:

$$\tau_m = \tau_0 + \tau_1 p_m.$$

When $\tau_0 < 0$, then, depending on the level of regulation, the tax rate may be positive or negative. If $\tau_m > 0$, then homeowners are taxed for choosing strict regulation that lead to high real estate prices. If $\tau_m < 0$, then owners are rewarded for selecting lax regulation. The policy is purely redistributive, i.e. net transfers in the economy are equal to zero:

$$\sum_{m \in \mathcal{M}} \tau_m p_m N_m^O = 0. \tag{1.7.1}$$

The parameters of the tax function are fixed as follows. I set $\tau_1$ so that the tax rate is not too sensitive to price levels. I choose $\tau_1 = 1.68 \times 10^{-7}$: at this level a move along the interquartile range of the distribution of house prices in the benchmark economy (from $129,570 to $189,120) yields a 1 percentage point change in the tax rate. At this level of $\tau_1$, the value of $\tau_0$ that satisfies equation (1.7.1) is $-0.0384$. Local tax rates in this experiment range from -2.4% to 1.9%. The remaining parameters are as in the benchmark economy. The results of the experiment are summarized in Table 1.12.

[65] This solution was originally proposed by Glaeser and Gyourko (2008). They suggested a reduction from the current $1,000,000 to $300,000.

[66] https://www.irs.gov/pub/irs-pdf/p523.pdf

The disincentives to regulate brought by the tax lead to a significant reduction in the level of regulation: the average $\zeta^{\text{reg}}$ falls from 0.07 to 0.062. As a result, more labor locates in productive and previously expensive areas and both output and wages grow by about 1.5%. Wage inequality across MSAs falls by almost 5%. House prices fall by 25% on average, and the price dispersion across locations dwindles to just 52% of the benchmark level. The average homeownership rate increases from 73.4% to 82%. The ratio of ownership rates of high to low skilled workers drops from 1.2 to 1.12. As in the previous policy experiment, most of the decline in prices occurs in cities that were highly regulated in the benchmark economy: in New York they drop by 59% and in San Francisco by 45%.

## 1.8 Conclusions

In this paper, I argue that housing supply regulation and the forces that drive it are crucial to understand the divergent dynamics of labor and housing markets in the U.S. Since the 1980s, there has a been an increase in sorting of skilled workers to more productive and expensive metro areas. The impact of higher sorting on wage and housing price dispersion across MSAs was amplified by the endogenously growing regulatory constraints to housing supply. In order to study this channel quantitatively, I build an equilibrium model in which the distributions of labor, wages and housing prices across metro areas are determined endogenously, and housing supply regulation is chosen by local residents in a political process. To assess the magnitude of the amplification effect of the endogenous regulation mechanism, I construct a counterfactual scenario in which regulation remains at the level of 1980, but exogenous productivities, skill supply and total population are at the level of 2007. The amplification effect is sizable: endogenous regulation choices account for 23% of the rise in wage inequality and 85% of the increase in house price dispersion between 1980 and 2007. Moreover, the rise of regulation reduces productivity due to misallocation of labor, and results in the output loss of 2.1%.

These negative effects arise because regulation is determined locally and residents in each community do not internalize the consequences of their choices for the rest of the economy. In a policy experiment where the federal government provides monetary incentives to reduce regulation, I find that output would be 1.5% higher, wage differences 5% smaller, and average house prices 25% lower.

# Chapter 2

# Opportunity to Move: Macroeconomic Effects of Relocation Subsidies

*"I want to get out of here, but I can't... I got no money. I'm stuck."*
Charlie LeDuff, "Detroit" (2014)

## 2.1 Introduction

In 2010 the unemployment rate in the U.S. hit 9.6%, a level not seen since early 1980s. As most commentators have focused on the national rate of unemployment, the tremendous regional differences received little attention (Figure 2.1). The aggregate numbers hid the fact that some areas managed to live through the Great Recession largely unaffected, while others took the hit of the crisis. In 2010 metropolitan areas with booming economies such as Omaha, Washington DC, and Oklahoma City posted unemployment rates of 5-6%, whereas some of the hardest-hit cities, such as Detroit and Las Vegas, saw their unemployment climb above 13%.[1] Besides high degree of variation across space, local unemployment exhibits strong persistence over time: cities with high unemployment rates in a given year also have high unemployment in the following years (Figure 2.2).[2]

These large and persistent differences imply that many unemployed individuals keep searching for jobs in locations with scarce job opportunities instead of moving to places with more abundant jobs. This may happen for several reasons. First, individuals may face high moving costs, both monetary and non-monetary. The non-monetary costs include the disutility of moving away from family, friends and familiar environment, and are likely to be sizable. They also include psychological stress associated with moving, time spent on organizing the move and finding a new home, etc. All these costs may be high enough that moving is not optimal even though the current location does not offer the best economic environment. Second, even if relocation is optimal given costs, individuals may simply not have enough savings or not be able to borrow to finance the

[1] In this paper I use the notions of *metropolitan statistical area* (MSA) and *city* interchangeably, as is common in the literature. For the purposes of this paper, MSAs are more relevant than cities since the former constitute a contiguous labor market and often comprise several cities.

[2] The high persistence of local joblessness can be explained by slow response of both population and in- and out-migration rates to regional productivity and labor market shocks, as shown by Davis, Fisher and Veracierto (2014) and Nenov (2015).

move. The financial constraint may be especially relevant for the low-skilled unemployed. Finally, there may be significant information barriers, whereby unemployed workers have imprecise information about labor markets in other locations.

These moving constraints diminish the ability of workers to respond to local shocks and, as a result, may have adverse macroeconomic effects. In particular, the reduced ability to move may lead to higher national unemployment and lower productivity – the effects I explore in this paper. The effect of moving constraints on unemployment arises via two channels. First, the constraints may lead to higher geographic mismatch of job openings and job seekers: a situation in which a person cannot find a job in location $A$, and there is a job he is looking for in location $B$, but he cannot relocate from $A$ to $B$. Second, if, due to moving constraints, an individual only searches locally, the duration of his search is likely to be longer than if he also searched in other locations. Longer unemployment spells will mechanically result in a higher national unemployment.[3] The effect of moving constraints on productivity may arise if they prevent labor from allocating efficiently across space.

In this paper, I study the effects of *relocation subsidies*, a policy first proposed by Moretti (2012), on unemployment, productivity and welfare. Currently, the U.S. unemployment insurance system does not provide incentives for the unemployed workers to look for jobs outside their local labor markets. Relocation subsidies, on the other hand, encourage workers to move to more vibrant labor markets. The question I ask in this paper is whether relocation subsidies combined with unemployment benefits is a better unemployment insurance policy than the benefits alone.

To study the effects of the subsidies, I build a job search model with multiple locations in which moving constraints explicitly enter the decision-making of a job-seeker, and thus affect geographic mobility of labor, as well as local and national unemployment. The economy consists of multiple locations, each with its own labor and housing market. The variation in unemployment stems from different job creation rates across locations. The model economy is populated by finitely lived individuals with heterogeneous skills. An individual may be employed or unemployed, and in the latter case he receives unemployment benefits. The benefits are financed by taxes on labor income. Workers can move between locations at any time. The decision to migrate depends on employment status, wages, housing rents, the state of the labor market (i.e. the job creation rate), and preferences for locations. The ability to migrate is inhibited by the following moving constraints: (1) moving cost, (2) borrowing limit, and (3) cross-location job search friction. The moving cost is a lump-sum amount paid by a worker who relocates. For some workers the cost is so high that moving would be suboptimal even if another location offers better wages or rent. The borrowing limit places a constraint on an individual's ability to finance the move from external sources. Some workers may find it optimal to move but they might not possess enough funds to finance the relocation. Finally, the cross-location search friction lowers the probability of receiving an outside offer as compared to a local offer.

I calibrate the model to the U.S. economy by targeting central facts about local and national labor and housing markets, and internal migration. In order to bring the model to the data, I split all metropolitan areas in the U.S. into four groups by wage earnings and unemployment rate: low wage-low unemployment, low wage-high unemployment,

[3]Andersson, Haltiwanger, Kutzbach, Pollakowski and Weinberg (2014) find that better job accessibility within an MSA reduces unemployment duration. The same result should hold for the cross-city job accessibility.

high wage-low unemployment, and high wage-high unemployment. Then I calibrate the parameters that describe labor and housing markets in the model so as to match the average statistics of the four groups of cities in the data.

Then I introduce a relocation subsidy that pays a fraction of the monetary moving costs to every unemployed worker willing to move. Together with unemployment benefits, the subsidies are financed by a proportional tax on labor income. Essentially, the government expands the unemployment insurance system by adding the moving subsidies.

I find that during 2009-2011, a period of high unemployment in the aftermath of the Great Recession, a moving subsidy that pays 50% of moving expenses would reduce the national unemployment rate by 0.36 percentage points (or 4.8%) and increase productivity by 1%.[4] The effect on productivity comes from the fact that moving subsidies put more individuals to work (extensive margin) and also make them move to more productive locations (intensive margin): for example, population of the low-unemployment high-wage group of cities expands by 6%. Importantly, these subsidies cost nothing to the taxpayer, since the additional expenses on moving subsidies are offset by a reduction of outlays for unemployment benefits. In other words, I find that unemployment benefits combined with relocation subsidies constitute a more efficient unemployment insurance system than unemployment benefits only. The policy, however, does not produce a positive welfare effect. The subsidies attract workers toward more productive places, which leads to higher housing prices there. Even though the consumption of goods increases after the introduction of the subsidies, the consumption of housing falls.[5]

This paper is related to several strands of literature. One of the first studies to document the variation of local unemployment rates in the U.S. is Blanchard and Katz (1992). In a more recent study, Rappaport (2012) reports large and persistent differences in unemployment across metropolitan areas and argues that they can be explained by skill mismatch, differences in amenities, and high moving costs.

The role of moving costs for geographic mobility is studied in Kennan and Walker, 2011, Bayer and Juessen (2012) and others. Coen-Pirani (2010), Lkhagvasuren (2012), Beaudry, Green and Sand (2014) and Schmutz and Sidibé (2016) study the importance of moving costs and/or cross-location job search frictions in a general equilibrium framework. These papers follow a positive approach and take the moving cost as given. In this paper, I consider a policy that can change the moving cost for unemployed migrants.

This paper is connected to the literature on optimal unemployment insurance over the business cycle, see Jung and Kuester (2015), Mitman and Rabinovich (2015), Kroft and Notowidigdo (2016) and Landais, Michaillat and Saez (2016). A more related line of research has studied the interaction between geographic mobility and unemployment policies. Hassler, Rodríguez Mora, Storesletten and Zilibotti (2005) propose a theory in which societies with lower geographic mobility vote for higher unemployment insurance. On the empirical side, Goss and Paul (1990) argue that during recessions unemployment benefits are likely to retard out-migration of the involuntarily unemployed. At the same time, Rupert and Wasmer (2012) find that the size of unemployment benefits has a tiny effect on mobility within cities. In this paper, unemployment policy is specifically

[4]The calibrated moving cost is $8,425, hence a subsidy that covers half of moving costs is equal to $4,213.

[5]This result is similar to the one found by Eeckhout and Guner (2015). They build a spatial model and study optimal federal income taxes that take into account differences in local prices and maximize welfare. Even though alternative taxation raises output by 1.6%, it has virtually no effect on welfare because reallocation of workers to more productive cities leads to a rise in housing prices and negates the positive effects of higher wages.

designed to stimulate mobility.

This paper is also related to the literature on spatial mismatch: the unemployment that emerges when workers and firms which would find it mutually optimal to form a match do not do so because they are spatially separated. Using state-level data, Herz and van Rens (2015) find that the mismatch is virtually nonexistent. However, differences in wages and unemployment between MSAs in many large U.S. states are comparable to the cross-state differences. Şahin, Song, Topa and Violante (2014) use county-level data and estimate that geographic mismatch contributed 0.45 percentage points (about 5%) to the national unemployment rate in 2010, however their modeling framework is silent about the sources of the mismatch. Analysis in the current paper suggests that moving constraints might be an important source of the mismatch.

In this paper, I do not distinguish between owner-occupied and rental housing. The evidence on the importance of homeownership for internal migration and local unemployment is mixed. Head and Lloyd-Ellis (2012) find that the effect of homeownership on unemployment is small in booms but can become significant in recessions. Karahan and Rhee (2014) focus on the downpayment constraint as the key friction. They reckon that the housing bust during the Great Recession reduced migration and increased the dispersion of local unemployment rates, as well as contributed 0.5 percentage points to aggregate unemployment. Several other studies, e.g. Schulhofer-Wohl (2012), Demyanyk, Hryshko, Luengo-Prado and Sørensen (2016) and Valetta (2013), evaluated the effect of underwater mortgages on internal migration and unemployment in the U.S., and found that negative home equity does not reduce labor mobility or increase unemployment. Oswald (2016) studies the importance of mortgage interest deduction for labor mobility and finds a very small effect. At the same time, Ferreira, Gyourko and Tracy (2010) and Sterk (2015) find that negative home equity does reduce geographic mobility.

This paper is also connected to the recent literature about the importance of internal migration in mitigating negative local shocks during the Great Recession. Monras (2015) finds that during the Great Recession internal migration mitigated up to one-third of the effect of the recession on wages in the hardest-hit locations. At the same time, Yagan (2014) argues that at the individual level migration provided very little insurance against negative local shocks in the Great Recession.

Research on policies that promote geographic mobility has been scarce. Ransom (2015) estimates a structural model of individual migration decisions, and studies the response of migration to local labor market shocks in the U.S. In a counterfactual exercise he introduces a moving subsidy, and finds that it induces migration of the unemployed. Yet his paper abstracts from macroeconomic effects of the subsidies. Bryan, Chowdhury and Mobarak (2014) ran a field experiment in Bangladesh in which they randomly assigned a monetary incentive to rural households to temporarily migrate to urban areas. They find that consumption of treated households rises and their propensity to migrate again, without the subsidy, goes up.

The paper proceeds as follows. Section 2.2 outlines the model without moving subsidies. Section 2.3 describes the calibration of the model to the U.S. data. Section 2.4 introduces moving subsidies into the calibrated economy and analyzes their effects. Section 2.5 concludes.

## 2.2 Environment

The model economy consists of $I$ locations, each with its own labor and housing markets.[6] Workers can move across locations at any time after paying a one-time moving cost $\kappa$. Time is discrete. Each location $i$ is characterized by TFP level $A_i$, job offer arrival rate $\theta_i$, and a construction cost parameter $\chi_i$. The size of total labor force in all cities is normalized to 1.

### 2.2.1 Workers

The economy is populated by high and low skilled workers, $s \in \{L, H\}$. Their measures in the entire economy are $\lambda_H$ and $\lambda_L$, with $\lambda_H + \lambda_L = 1$.

**Preferences.** Workers live and work $T$ periods. They consume a homogeneous good and rent housing. They have the following Stone-Geary preferences on the two types of consumption:

$$\tilde{v}(c,h) = \ln \left[ c^{1-\gamma} (h - h_{\min})^{\gamma} \right], \tag{2.2.1}$$

where $h_{\min}$ represents the minimum amount of housing everyone must rent.[7] Individuals discount future utility with a factor $\beta$.

In addition, individual utility depends on location in two ways. First, every individual has a "preferred" location $i^*$ which is fixed for life (*permanent component*). If a worker lives outside his preferred location, he suffers a disutility $\mu$. This component is described by the function $\mu(i^*, i)$:

$$\mu(i^*, i) = \begin{cases} 0, \text{ if } i = i^* \\ \mu < 0, \text{ if } i \neq i^* \end{cases}$$

Second, every period a worker receives an *i.i.d.* shock to utility $\varepsilon(j)$ which is associated with choosing to live in location $j$ next period (*transitory component*). As common in the discrete-choice literature, I assume that the shock follows the extreme value type 1 distribution with parameters $\mu_\varepsilon$ and $\sigma_\varepsilon$, and that it has zero mean.[8] This shock should be interpreted as the utility cost or benefit of moving to a given location, not related to the location's job and housing market characteristics. Hence the instantaneous utility of a worker who resides in location $i$, while preferring to live in location $i^*$, and will move to location $j$ next period is given by

$$\tilde{v}(c,h) + \mu(i^*, i) + \varepsilon(j). \tag{2.2.2}$$

**Labor market.** A worker can be employed or unemployed. The measures of employed and unemployed workers of skill $s$, age $a$, living in city $i$ are denoted by $n(s,a,i)$ and $u(s,a,i)$, respectively. The total employment and unemployment in location $i$ are denoted by $n_i$ and $u_i$. Employed workers earn wage $w(s,a,i)$ and unemployed workers

[6] This model builds upon the model of "islands" Lucas and Prescott (1974), and is closely related to the more recent model of Alvarez and Shimer (2011).

[7] Stone-Geary preferences are widely used to model non-homothetic demand. In the current context, they imply a negative relationship between income and the share of income spent on housing. See Ganong and Shoag (2015) for empirical evidence.

[8] The density function of the extreme value type 1 distribution with parameters $\mu_\varepsilon$ and $\sigma_\varepsilon$ is $f(x) = \exp(-\exp(-(x-\mu_\varepsilon)/\sigma_\varepsilon))$. The mean of a random variable with such distribution is $\mu_\varepsilon + \sigma_\varepsilon \bar{\gamma}$, where $\bar{\gamma} \approx 0.5772$ is the Euler-Mascheroni constant. The variance is $\sigma_\varepsilon^2 \pi^2/6$. The shock has zero mean if $\mu_\varepsilon = -\sigma_\varepsilon \bar{\gamma}$.

receive benefits $b(s,a,i)$, both of which depend on skill, age and location. I assume that the benefits for each type are a fraction of wage for the same type: $b(s,a,i) = \bar{\upsilon}w(s,a,i)$. The benefits do not expire.[9]

Newborn (age-1) workers enter the economy unemployed. Every period a worker receives an offer from the local labor market with probability $\theta_i$, and an offer from location $j$ with probability $\Delta\theta_j$. There is on-the-job search and the offer arrival rates do not depend on employment status. An individual cannot receive more than one offer per period. The parameter $\Delta \leq 1$ is the cross-city search friction. The search friction is necessary for two reasons. First, according to the evidence surveyed in Ioannides and Loury (2004), around half of jobs are found through social networks. Social networks have local nature, i.e. for most people the majority of their acquaintances live in the same geographical area. Second, relatively few individuals actually search for jobs in other locations. Marinescu and Rathelot (2014) analyzed job applications on CareerBuilder.com, a leading job board in the U.S., and found that only 16% were sent to employers in other states.

**Migration.** While most labor market models with multiple locations do not allow job search across locations or moving without a job offer, in this model any worker is free to move to any city at any time. If a worker living in $i$ receives an offer from $j$ and moves there, he does not experience a spell of unemployment and starts the new job in the next period. However, if a worker moves to $j$ without an offer, he must start there unemployed.

Relocation to another city implies a monetary moving cost $\kappa$ which is independent of age or skill level.[10] On the other hand, $\mu(i^*, j) - \mu(i^*, i)$ captures the utility loss or gain from moving for a worker whose preferred location is $i^*$. This non-monetary cost/benefit may capture many components, such as an idiosyncratic preference for location-specific amenities, cost of separating from friends and family or benefit of reuniting with them, etc.

**Budget Constraint.** A worker can save or borrow up to a limit $B$ at an exogenous interest rate $r$. Income is taxed at rate $\tau$. Let $y(s,a,i)$, which is equal to $w(s,a,i)$ for an employed individual and $b(s,a,i)$ for an unemployed one, denote the labor income. Then the budget constraint of a worker with skill level $s$, aged $a < T$, in location $i$ are

$$c + p_i h + k' + \mathbb{I}_{\text{move}}\kappa \leq (1-\tau)y(s,a,i) + (1+r)k. \tag{2.2.3}$$

The value of the indicator function $\mathbb{I}_{\text{move}}$ is 1 if the worker moves to another location $j \neq i$, and 0 otherwise. In the last period of life ($a = T$) a worker does not migrate and consumes all assets, hence the last period's budget constraint is $c + p_i h \leq (1-\tau)y(s,a,i) + (1+r)k$.[11]

**Demand for Consumption Good and Housing.** Let $\tilde{y} \equiv (1-\tau)y$ denote the after-tax income. The maximization of the utility function (2.2.1) subject to the budget constraint (2.2.3) yields the demand function for the consumption good

$$c(\tilde{w} - \mathbb{I}_{\text{move}}\kappa, p, k, k') = (1-\gamma)\left(\tilde{y} - \mathbb{I}_{\text{move}}\kappa + (1+r)k - k'\right) - (1-\gamma)ph_{\min}, \tag{2.2.4}$$

[9]In the U.S., unemployment benefits expire after 26 weeks though their duration may be prolonged in a recession. In Section 2.3.2 I argue that assuming the 26-week expiration would have a negligible quantitative effect on the calibrated model, whereas it would increase the computational cost significantly.

[10]Amior (2015) finds that the high-skilled are more mobile because they expect larger surpluses accruing to job matches. Notowidigdo (2013) attributes lower mobility of the low-skilled to a lower incidence of shocks to demand for low-skilled labor. However, neither study finds that moving costs depend on skill level.

[11] Note that unemployment benefits in the U.S. are taxable just as any other type of labor income.

and housing

$$h(\tilde{w} - \mathbb{I}_{\text{move}}\kappa, p, k, k') = \frac{\gamma}{p} \left(\tilde{y} - \mathbb{I}_{\text{move}}\kappa + (1+r)k - k'\right) + (1-\gamma)h_{\min}. \tag{2.2.5}$$

Then the indirect utility function is given by

$$v(\tilde{w} - \mathbb{I}_{\text{move}}\kappa, p, k, k') = \ln\left[\gamma^{\gamma}(1-\gamma)^{1-\gamma}\left[\tilde{w} - \mathbb{I}_{\text{move}}\kappa + (1+r)k - k' - ph_{\min}\right]p^{-\gamma}\right]. \tag{2.2.6}$$

### 2.2.2 Production of the Consumption Good

In every location there is a representative firm that hires labor of both skills to produce a homogeneous consumption good. The good is the numeraire, traded across cities at zero cost. The production technology is given by

$$Y_i = A_i\left((\psi_L n_{Li})^{\eta} + (\psi_H n_{Hi})^{\eta}\right)^{\frac{1}{\eta}},$$

where $n_{si}$ is amount of labor of skill $s$ in city $i$ in efficiency units: $n_{si} \equiv \sum_{a=1}^{T}\phi(a)n(s,a,i)$. Parameter $\psi_s$ represents the productivity of a worker with skill level $s$, while function $\phi(a)$ accounts for the age-specific productivity of a worker.[12]

Firms maximize profit by selecting the amount of labor of each type. The equilibrium wage for an $s$-skilled worker who is $a$ periods old and lives in city $i$ is given by

$$w(s,a,i) = A_i\psi_s\phi(a)\cdot\frac{\left((\psi_L n_{Li})^{\eta} + (\psi_H n_{Hi})^{\eta}\right)^{\frac{1-\eta}{\eta}}}{(\psi_s n_{si})^{1-\eta}}. \tag{2.2.7}$$

The wage of an $s$-skilled individual is lower if the skill is abundant locally, however, when skills are complementary ($\eta < 1$), the wage is increasing in the supply of the other skill.

### 2.2.3 Housing Market

The housing market is modeled along the lines of the Rosen-Roback spatial equilibrium model.[13] In every city housing is built by a representative developer. The developers own houses and rent them out to the inhabitants.[14] I assume that developers are also landlords, i.e. they own the land the houses are built on. I assume that they have zero measure in the economy. However, in the quantitative section, in order to capture welfare effects, I redistribute the revenues of the developers among all workers in the economy.

Housing is built using the consumption good and land. Each city has a fixed land endowment $\Lambda_i$. The amount of housing built in the current period is equal to $q_{it}\Lambda_i$: the size of land plot $\Lambda_i$ times the average number of stories per unit of land $q_i$. Housing depreciates at rate $\rho$, and the residential stock that remains from the previous period is $(1-\rho)Q_{i,t-1}\Lambda_i$. Thus the supply of housing at time $t$ is

$$Q_{it}\Lambda_i = q_{it}\Lambda_i + (1-\rho)Q_{i,t-1}\Lambda_i.$$

[12] For computational reasons I do not differentiate between age and experience.

[13] See Rosen (1979), Roback (1982) and Glaeser (2008) for details.

[14] I do not distinguish between rented and owned housing. In their studies of responses of migration to local labor market shocks, Davis, Fisher and Veracierto (2014) and Nenov (2015) find that housing plays a small role. Thus abstracting from homeownership should not affect the analysis of the effects of moving subsidies on labor reallocation.

The cost of building $q_{it}$ new stories over the $(1-\rho)Q_{i,t-1}$ stories that remain from the previous period is $\chi_i\left(q_{it}+(1-\rho)Q_{i,t-1}\right)^{\zeta_i}$, where $\zeta_i$ and $\chi_i>0$ are cost parameters. This cost function exhibits urban congestion: it is increasingly costly to build new houses if a city already has plenty of them. Existing housing cannot be demolished.

The number of stories is a continuous variable. In this case, since the marginal cost of construction increases in the existing amount of housing, the developer will optimally choose to use for construction all available land, $\Lambda_i$. Therefore, the problem of the developer is reduced to the choice of the number of stories and is given by

$$\max_{q_{it}\geq 0}\left\{p_{it}\left(q_{it}\Lambda_i+(1-\rho)Q_{i,t-1}\right)-\chi_i\left(q_{it}+(1-\rho)\bar{q}_{i,t-1}\right)^{\zeta_i}\Lambda_i\right\}.$$

For an interior solution, the profit-maximizing housing supply function is[15]

$$Q(p_i)=\left(\frac{p_i}{\chi_i\zeta_i}\right)^{\frac{1}{\zeta_i-1}}\Lambda_i, \tag{2.2.8}$$

where $\frac{1}{\zeta_i-1}$ is the price elasticity of housing supply in city $i$.

Using the demand function for housing (2.2.5), we can define the purchasing power of inhabitants of city $i$, $\Pi_i$, as the sum of individual demands for housing. Therefore the aggregate demand for housing in city $i$ is

$$Q^d(p_i)=\frac{\gamma}{p_i}\Pi_i+(1-\gamma)h_{\min}(n_i+u_i). \tag{2.2.9}$$

In equilibrium, $Q(p_i)=Q^d(p_i)$. Thus, combining equations (2.2.8) and (2.2.9), we can define the equilibrium rent $p_i$ implicitly as[16]

$$\left(\frac{1}{\zeta_i\chi_i}\right)^{\frac{1}{\zeta_i-1}}\Lambda_i p_i^{\frac{\zeta_i}{\zeta_i-1}}-(1-\gamma)h_{\min}p_i(n_i+u_i)=\gamma\Pi_i. \tag{2.2.10}$$

### 2.2.4 Government

There is a government whose function is to provide unemployment benefits. To do this, it levies a proportional income tax $\tau$ on wages and unemployment benefits earned by workers.[17] The government budget must balance, i.e. tax revenues must equal the expenditures on unemployment benefits:

$$\sum_{s=L,H}\sum_{a=1}^{T}\sum_{i=1}^{I}\left(\tau w(s,a,i)n(s,a,i)+\tau b(s,a,i)u(s,a,i)\right)=\sum_{s=L,H}\sum_{a=1}^{T}\sum_{i=1}^{I}b(s,a,i)u(s,a,i). \tag{2.2.11}$$

### 2.2.5 Workers' Decisions

Every period a worker decides (1) how much to save or borrow, (2) whether to move to another location, and (3) how to split his disposable income between consumption and

[15]The case of $q_{it}=0$ is trivial and is not analyzed here since in a stationary economy $q_{it}>0$.
[16]It is straightforward to show that the solution $p_i$ exists and is unique.
[17]See footnote 11.

housing, in order to maximize the discounted sum of per-period utilities (2.2.1) subject to the budget constraint (2.2.3) and the borrowing limit $B$.

**Timing.** Each period consists of the following sequence of events. First, production of the consumption good takes place, and workers receive wage payments. After this, workers observe a realization of the vector of utility shocks. At the same time, new job offers are generated and randomly distributed among all workers according to the probabilities specified in Section 2.2.1. Then migration decisions are made. Those who received an offer from another location may move by accepting the offer. Workers may also move to another location without a job offer from there. Accepted offers only turn into jobs starting from the next period. Then the developers build housing to accommodate the demand. Next workers spend their disposable income on consumption, housing and moving expenses. If the expenses are below labor and capital income, they save the difference. Otherwise they borrow to cover the expenses, but up to the limit $B$. After that, migration occurs. Finally, a fraction $\delta$ of existing jobs is randomly destroyed.[18]

**Bellman Equations.** The *individual state* of a worker is $(s, a, i^*, i, k, o, \varepsilon)$, where $s$ is skill, $a$ is age, $i^*$ is preferred location, $i$ is current location, $k$ is savings, and $o$ is the job offer status: no offer ($o = o_N$) or offer from location $j$ ($o = o_j$). Finally, $\varepsilon$ is the vector of the realizations of utility shocks for each choice of location. The *aggregate state* is described by the distribution of labor across individual states $\Phi : \mathcal{X} \to \mathbb{R}_+$, where $\mathcal{X} \equiv \{L, H\} \times \{1, ..., T\} \times \{1, ..., I\} \times \{1, ..., I\} \times [B, \infty) \times \{o_N, o_1, ..., o_I\} \times \mathbb{R}^I$ is the space of individual states. The aggregate state determines the distribution of labor and housing prices across locations, $w(m, s, a; \Phi)$ and $p_i(\Phi)$, but workers take the prices as given.

A worker can be in four possible situations with respect to current employment status and availability of a job offer: (1) employed worker without a job offer, (2) employed worker with a job offer, (3) unemployed worker without a job offer, and (4) unemployed worker with a job offer. Each of these possibilities dictates a specific form of the value function, but all of them describe a simultaneous choice of location and assets.

*Situation (1): employed worker without a job offer.* In this case a worker can stay in the current location and retain his job in the next period with probability $1 - \delta$. Alternatively, the individual can move to another location $l$ but, since he did not receive a job offer from $l$, he will have to start next period unemployed. The value function of this worker describes the decision between staying in the current location $i$ and moving to location $l$, and the decision on asset holdings for each location choice, such that the budget and the borrowing constraints are satisfied:

$$\begin{aligned}
&\mathcal{W}(s, a, i^*, i, k, o_N, \varepsilon; \Phi) \; = \\
&\quad \max \Bigg\{ \max_{k'} \Big\{ v(\tilde{w}(s, a, i; \Phi), p_i(\Phi), k, k') + \varepsilon(i) - \mu(i^*, i) + \beta(1-\delta)\mathrm{E}\left[\mathcal{W}(s, a+1, i^*, i, k', o', \varepsilon'; \Phi')\right] \\
&\qquad\qquad\qquad + \beta\delta\mathrm{E}\left[\mathcal{U}(s, a+1, i^*, i, k', o', \varepsilon'; \Phi')\right] \Big\}, \\
&\qquad \max_{l \neq i} \Big\{ \max_{k'} \Big\{ v(\tilde{w}(s, a, i; \Phi) - \kappa, p_i(\Phi), k, k') + \varepsilon(l) - \mu(i^*, i) + \beta\mathrm{E}\left[\mathcal{U}(s, a+1, i^*, l, k', o', \varepsilon'; \Phi')\right] \Big\} \Big\} \Bigg\}
\end{aligned}$$

[18]Since an accepted offer turns into a job from the next period, the new job cannot be destroyed before a worker spent there at least one period, and therefore workers who migrate are immune to job destruction. This assumption should not affect the results in model period is short.

$$\text{such that} \begin{cases} c + p_i(\Phi)h + k' \le \tilde{w}(s,a,i;\Phi) + (1+r)k \text{ , if worker stays in location } i \\ c + p_i(\Phi)h + k' + \kappa \le \tilde{w}(s,a,i;\Phi) + (1+r)k \text{ , if worker moves to location } l \neq i \end{cases}$$
$$\text{and} \quad k' \ge B, \qquad (2.2.12)$$

where $v(\tilde{w}(s,a,i;\Phi) - \mathbb{I}_{\text{move}}\kappa, p_i(\Phi), k, k')$ is the indirect utility of disposable income (see equation 2.2.6). The expectation of the future value function is taken with respect to the type of job offer and the vector of future utility shocks $\varepsilon'$, and can be written as

$$\mathrm{E}\left[\mathcal{W}(s,a+1,i^*,i,k',o',\varepsilon';\Phi')\right] = \int \Bigg[\theta_i \mathcal{W}(s,a+1,i^*,i,k',o_i,\varepsilon';\Phi') + \sum_{j\neq i} \Delta\theta_j \mathcal{W}(s,a+1,i^*,i,k',o_j,\varepsilon';\Phi')$$
$$+ \left(1 - \theta_i - \sum_{j\neq i} \Delta\theta_j\right) \mathcal{W}(s,a+1,i^*,i,k',o_N,\varepsilon';\Phi')\Bigg] d\varphi(\varepsilon'), \quad (2.2.13)$$

where $\theta_j$ is the probability of receiving a job offer from location $j$ (see section 2.2.1), and $\varphi(\varepsilon')$ is the joint distribution of the vector of the utility shocks (*i.i.d.* extreme value type 1). The expectation of the value of being unemployed is defined analogously. When deciding on future location $j$, a worker takes into account both the expected value of this choice in the next period and the current random utility associated with choosing location $j$. All else equal, the worker is more likely to choose to move to his preferred location $i^*$ in order to avoid the utility penalty brought by $\mu(i^*, i)$.

*Situation (2): employed worker with job offer from city $j \neq i$.*[19] In this case a worker can also stay in the current location and keep his job in the next period with probability $1 - \delta$. However, he can also take up the offer from location $j$ and move there without having to go through a spell of unemployment. As usual, he can also move to another location $l \neq j$, but then he will have to start the next period without a job. The value function describes the decision on whether to stay in $i$, move to $j$ or to $l \neq i, j$, and the decision on asset holdings for each location choice, such that the budget and the borrowing constraints hold:

$$\mathcal{W}(s,a,i^*,i,k,o_j,\varepsilon;\Phi) =$$
$$\max\Bigg\{ \max_{k'} \Big\{ v(\tilde{w}(s,a,i;\Phi), p_i(\Phi), k, k') + \varepsilon(i) - \mu(i^*,i) + \beta(1-\delta)\mathrm{E}\left[\mathcal{W}(s,a+1,i^*,i,k',o',\varepsilon';\Phi')\right]$$
$$+ \beta\delta\mathrm{E}\left[\mathcal{U}(s,a+1,i^*,i,k',o',\varepsilon';\Phi')\right] \Big\},$$
$$\max_{k'} \Big\{ v(\tilde{w}(s,a,i;\Phi) - \kappa, p_i(\Phi), k, k') + \varepsilon(j) - \mu(i^*,i) + \beta\mathrm{E}\left[\mathcal{W}(s,a+1,i^*,j,k',o',\varepsilon';\Phi')\right] \Big\},$$
$$\max_{l\neq i,j} \Big\{ \max_{k'} \Big\{ v(\tilde{w}(s,a,i;\Phi) - \kappa, p_i(\Phi), k, k') + \varepsilon(l) - \mu(i^*,i) + \beta\mathrm{E}\left[\mathcal{U}(s,a+1,i^*,l,k',o',\varepsilon';\Phi')\right] \Big\}\Big\}\Bigg\}$$

$$\text{such that} \begin{cases} c + p_i(\Phi)h + k' \le \tilde{w}(s,a,i;\Phi) + (1+r)k \text{ , if worker stays in location } i \\ c + p_i(\Phi)h + k' + \kappa \le \tilde{w}(s,a,i;\Phi) + (1+r)k \text{ , if worker moves to location } j \neq i \text{ or } l \neq i,j \end{cases}$$
$$\text{and} \quad k' \ge B. \qquad (2.2.14)$$

*Situation (3): unemployed worker without a job offer.* Such worker can either keep searching in his current location $i$ or move to search in location $l$. The value function

[19] An employed worker never accepts an offer for a job in his current city since it is exactly the same as his current job. Hence if $j = i$, this situation is the same as the situation (1) in which no offer arrives.

of the worker describes the decision between remaining in $i$ and moving to $l$, and the decision on assets for each location, such that the budget and the borrowing constraints are satisfied:

$$\mathcal{U}(s,a,i^*,i,k,o_N,\varepsilon;\Phi) = \max\left\{ \max_{k'}\left\{v(\tilde{b}(s,a,i;\Phi),p_i(\Phi),k,k') + \varepsilon(i) - \mu(i^*,i) + \beta \mathrm{E}\left[\mathcal{U}(s,a+1,i^*,i,k',o',\varepsilon';\Phi')\right]\right\}, \max_{l\neq i}\left\{ \max_{k'}\left\{v(\tilde{b}(s,a,i;\Phi)-\kappa,p_i(\Phi),k,k') + \varepsilon(l) - \mu(i^*,i) + \beta \mathrm{E}\left[\mathcal{U}(s,a+1,i^*,l,k',o',\varepsilon';\Phi')\right]\right\}\right\}\right\}$$

$$\text{such that } \begin{cases} c + p_i(\Phi)h + k' \leq \tilde{b}(s,a,i;\Phi) + (1+r)k \text{ , if worker stays in location } i \\ c + p_i(\Phi)h + k' + \kappa \leq \tilde{b}(s,a,i;\Phi) + (1+r)k \text{ , if worker moves to location } l \neq i \end{cases}$$
$$\text{and } \quad k' \geq B. \tag{2.2.15}$$

*Situation (4): unemployed worker with job offer from city $j$.* In this case the worker can always reject the offer and remain unemployed in his current location. On the other hand, if the offer comes from his current location ($j = i$), then he may simply accept the offer without incurring any cost. If the offer arrives from location $j \neq i$, then, in order to accept the offer, the worker must pay the moving cost $\kappa$. Alternatively, he can relocate to another location $l \neq i, j$ and search there. The value function of this worker describes the decision between keeping searching in location $i$, accepting a job offer from location $j$ (where $j$ possibly equals $i$) or moving to search to another location $l \neq i, j$, and the decision on asset holdings for each location choice, such that the budget and the borrowing constraints are satisfied:

$$\mathcal{U}(s,a,i^*,i,k,o_j,\varepsilon;\Phi) = \max\left\{ \max_{k'}\left\{v(\tilde{b}(s,a,i;\Phi),p_i(\Phi),k,k') + \varepsilon(i) - \mu(i^*,i) + \beta \mathrm{E}\left[\mathcal{U}(s,a+1,i^*,i,k',o',\varepsilon';\Phi')\right]\right\}, \max_{k'}\left\{v(\tilde{b}(s,a,i;\Phi)-\mathbb{I}_{i\neq j}\kappa,p_i(\Phi),k,k') + \varepsilon(j) - \mu(i^*,i) + \beta \mathrm{E}\left[\mathcal{W}(s,a+1,i^*,j,k',o',\varepsilon';\Phi')\right]\right\}, \max_{l\neq i,j}\left\{ \max_{k'}\left\{v(\tilde{b}(s,a,i;\Phi)-\kappa,p_i(\Phi),k,k') + \varepsilon(l) - \mu(i^*,i) + \beta \mathrm{E}\left[\mathcal{U}(s,a+1,i^*,l,k',o',\varepsilon';\Phi')\right]\right\}\right\}\right\}$$

$$\text{such that } \begin{cases} c + p_i(\Phi)h + k' \leq \tilde{b}(s,a,i;\Phi) + (1+r)k \text{ , if worker stays in location } i \\ c + p_i(\Phi)h + k' + \kappa \leq \tilde{b}(s,a,i;\Phi) + (1+r)k \text{ , if worker moves to location } j \neq i \text{ or } l \neq i,j \end{cases}$$
$$\text{and } \quad k' \geq B. \tag{2.2.16}$$

### 2.2.6 Distribution of Labor across Locations

Every period workers who reach age $T$ leave the labor force. There is no population growth, and generations are replaced as follows. Every worker of age 2 to $T_f$ ("fertile" ages) gives birth to an age-1 worker with probability $\frac{1}{T_f-1}$, which is the exactly the population replacement rate for the entire economy. Hence the measure of the newborns in location $i$ is equal to the average size of a cohort between ages 2 and $T_f$ in the location.

I assume that in every city $i$ fraction $\nu$ of newborns have location preference for the city they were born in (i.e. $i^* = i$), whereas location preferences of fraction $1-\nu$ of newborns are randomly distributed according to exogenous probabilities $\{\xi_{i^*}\}_{i^*=1}^{I}$. The distribution of the newborns by skill level is the same in all cities. Thus the size of the $s$-skilled newborn population in city $i$ whose preferred location is $i^*$ is given by

$$n(s,1,i;i^*) = (1-\nu)\lambda_s \xi_{i^*} \frac{1}{T_f - 1} \sum_{a=2}^{T_f} \sum_{s=L,H} [n(s,a,i) + u(s,a,i)] \\ + \mathbb{I}_{i=i^*} \cdot \nu \lambda_s \frac{1}{T_f - 1} \sum_{a=2}^{T_f} \sum_{s=L,H} [n(s,a,i) + u(s,a,i)] . \quad (2.2.17)$$

The fraction of workers born in location $i$ who have preference for $i$ is equal to $(1-\nu)\xi_i + \nu$. The measure of all $s$-skilled newborns in location $i$ is given by $n(s,1,i) = \sum_{i^*=1}^{I} n(s,1,i;i^*)$.

After workers are born, they can move across locations in order to maximize their lifetime expected utility. Since the utility shocks $\varepsilon$ are extreme value type 1, we can obtain closed-form expression for labor flows across locations.[20] Denote by $\bar{\mathcal{W}}(j|s,a,i^*,i,k,o)$ and $\bar{\mathcal{U}}(j|s,a,i^*,i,k,o)$ the employed and unemployed worker's value of choosing to live in $j$ next period, just before the realization of the utility shock.[21] Then, the *conditional choice probability* that an employed worker in state $(s,a,i^*,i,k,o)$ will choose location $j$ for the next period is

$$\frac{\exp\left(\bar{\mathcal{W}}(j|s,a,i^*,i,k,o)\right)^{\frac{1}{\sigma_\varepsilon}}}{\sum_{l=1}^{I} \exp\left(\bar{\mathcal{W}}(l|s,a,i^*,i,k,o)\right)^{\frac{1}{\sigma_\varepsilon}}}. \quad (2.2.18)$$

The conditional choice probability that an unemployed worker in state $(s,a,i^*,i,k,o)$ will choose location $j$ for the next period is

$$\frac{\exp\left(\bar{\mathcal{U}}(j|s,a,i^*,i,k,o)\right)^{\frac{1}{\sigma_\varepsilon}}}{\sum_{l=1}^{I} \exp\left(\bar{\mathcal{U}}(l|s,a,i^*,i,k,o)\right)^{\frac{1}{\sigma_\varepsilon}}}. \quad (2.2.19)$$

### 2.2.7 Equilibrium

The environment is stationary. There is no aggregate uncertainty at either national or city level. The equilibrium is solved numerically using the procedure outlined in Appendix B.1.

**Definition 2.2.1.** A *stationary equilibrium* consists of value functions $\mathcal{W}$ and $\mathcal{U}$ and the associated decision rules that determine optimal assets and whether or not to accept a job offer; conditional choice probabilities (2.2.18) and (2.2.19); tax rate $\tau$; wages $w(s,a,i)$ and rents $p_i$; distribution of workers across individuals states, $\Phi$; and a transition function $F : \mathcal{X} \to \mathcal{X}$ , such that: (1) the value functions maximize expected lifetime utility and the decision rules attain the value functions; (2) wages $w(s,a,i)$ and rents $p_i$ maximize profits of production firms and developers, respectively; (3) labor markets clear in every city (i.e. wages equalize demand for workers and supply of those who are not unemployed); (4) housing markets clear in every city; (5) the resource constraint holds (aggregate output is equal to aggregate consumption plus construction costs); (6) the government budget is balanced; (7) the distribution of labor is stationary: $F(\Phi) = \Phi$.

[20]The possibility of obtaining closed-form solutions for conditional choice probabilities in models with extreme value type 1 shocks was first discovered by McFadden (1973).

[21]In discrete-choice literature these functions are called *conditional value functions.*

## 2.3 Quantitative Analysis

### 2.3.1 Data

I use the individual-level data from the American Community Survey (ACS, Ruggles et al, 2015). In the benchmark calibration I will use the data for 2005-2007, a low-unemployment period.[22] Then I will perform an additional calibration for 2009-2011, a high-unemployment period (Figure 2.3).

**Workers.** The sample consists of household heads aged 25-64, who participate in the labor force, are not institutionalized, live in an MSA, and are not recent immigrants (i.e. lived in the U.S. last year).[23] The data counterparts of high and low-skilled workers are individuals with college degree or higher and those with a lower educational attainment. In my sample, 36.5% of individuals are high-skilled.

**Locations and labor markets.** The ACS identifies 283 MSAs for the years of interest.[24] However, for computational reasons, I cannot include 283 separate locations in the quantitative model.[25] Therefore I split the 283 metro areas into four groups: low unemployment and low wage ("LULW"), high unemployment and low wage ("HULW"), low unemployment and high wage ("LUHW"), and high unemployment and high wage ("HUHW"). A metro area belongs to a low/high group if its unemployment or wages are below/above the national mean in 2005-2007. Wages and unemployment rates for each group of cities are estimated from the ACS.[26] Since heads of households of prime age have higher propensity to be employed, the 2005-2007 average national unemployment rate in my sample (4.4%) is lower than the number reported by the BLS (4.8%). Table 2.1 summarizes the characteristics of the four groups.

**Migration.** In the ACS respondents are asked in which metropolitan area they lived a year ago. I define a person as a migrant if last year he lived in a different group of MSAs. The geographic mobility rate is calculated as the ratio of the number of individuals who are migrants in the current year to the population size in the previous year. The mobility rate between the four city groups in 2005-2007 is 1.99%. The mobility rate across *all* cities (i.e. both between and within city groups) is 2.67%.[27] Thus, even though I aggregate all the 283 MSAs into four groups only, I still capture 3/4 of all migration across metro areas. This should not be surprising since the MSAs are split into groups by unemployment and wages, and job-related reasons account for more than a half of interstate migration (Kaplan and Schulhofer-Wohl, 2015).

**Housing.** As a measure of housing costs, I use self-reported rents from the ACS. In order to control for the characteristics of a dwelling, I employ the hedonic-regression approach by Eeckhout, Pinheiro and Schmidheiny (2014) and estimate MSA-specific rent indices. The controls include the building type, floor area, the number of rooms, and the age of structure. Then I aggregate the MSA-specific rent indices into four indices for

[22] The individual data on migration at the MSA level is only available starting from 2005.

[23] I only include heads of household, since households often migrate together. If I did, my data on migration rates by income and education would be biased towards characteristics of married individuals.

[24] ACS only identifies metro areas with population of at least 100,000. There are 283 such metro areas in the U.S., and they are home to 82% of the labor force.

[25] The dynamic problem of a worker includes decisions regarding every possible future location, given current location. Therefore the state space expands exponentially in the number of locations.

[26] While estimates of the MSA-level unemployment are often taken from the Local Area Unemployment Statistics program by the Bureau of Labor Statistics, I need to use microdata to calculate unemployment rates specific to my sample.

[27] Empirical facts about internal mobility in the U.S. are summarized in Molloy et al (2011).

each of the city groups.

### 2.3.2 Parameter Values

The parameters of the model are calibrated to match central facts about local labor and housing markets, and internal migration in the U.S. in the 2005-2007 period. The model period is 1 month, and workers in the model live for 480 periods or 40 years (ages 25-64). The rest of the section describes the calibration. The calibrated parameters are summarized in Tables 2.2 and 2.3. Table 2.4 compares the targeted moments with the moments produced by the model. The calibrated parameters match the targeted moments nearly perfectly.

**Workers.** The annual discount factor $\beta$ is set to 0.96. The age-dependence of worker's productivity is specified as a quadratic function of age:

$$\phi(a) = \phi_0 + \phi_1 a + \phi_2 a^2. \tag{2.3.1}$$

Parameters $\phi_0$, $\phi_1$ and $\phi_2$ are estimated from the data on annual wage earnings for each age from 25 to 64 years old using the Current Population Survey (CPS) in 2005-2007 from the IPUMS (Flood et al, 2015). The estimating regression includes a college dummy and MSA fixed effects. The oldest fertile age is $T_f = 40$, following Monte and Ellis (2014) who document that 93% of all births in the U.S. in 2012 were to mothers younger than 40. The productivity of the low-skilled is normalized to $\psi_L = 1$, while the productivity of the high-skilled $\psi_H$ is calibrated to match the observed college premium.

The exogenous interest rate is set to $r = 0.04$.[28] In Appendix B.2, I show that the results of quantitative experiments performed in this paper are not sensitive to the value of the interest rate. The borrowing constraint $B$ is calibrated to match the fraction of households with negative or zero net worth in the data, which corresponds to the fraction of workers with $k \leq 0$ in the model. The proportion of such households was 19% in 2007, according to the analysis of the Survey of Consumer Finances by Michel et al (2012). The calibrated borrowing constraint is equivalent to \$2,165 (about 50% of average monthly wage income) in 2005 dollars.

**Locations and labor markets.** The exogenous productivity in the LULW group of cities is normalized to $A_{\text{LULW}} = 1$, while the productivities in other groups are set to match the mean wage in each group of cities relative to the mean wage in the LULW group. I assume that the job destruction rate $\delta$ is common to all cities, and equate it to the estimated average transition probability from employment to unemployment in 2005-2007: 0.0118 a month, following Gomes (2015). The job offer arrival rates, $\theta_i$, are calibrated to match the average unemployment rate in each group of cities $i$. Unemployment benefits are set to 50% of the wage rate for each combination of skill, age, and city, i.e. $b(x, a, i) = 0.5w(x, a, i)$.[29] The parameter that determines the elasticity of substitution between high and low-skilled labor, $\eta$, is set to 0.6, following Card (2009).[30]

[28]Since markets are incomplete and the borrowing constraint plays a crucial role in the model, to entice borrowing the interest rate must satisfy $\beta(1 + r) < 1$.

[29]According to the description of unemployment insurance by the Social Security Administration, "in most of the States, the formula is designed to compensate for a fraction of the usual weekly wage (normally about 50%)". See http://ssa.gov/policy/docs/progdesc/sspus/unemploy.pdf

[30]Using a similar CES production function, Card (2009) estimates that the elasticity of substitution between college-equivalent and high school-equivalent labor in the U.S. is between 1.5 and 2.5, which corresponds to $\eta$ between 0.33 and 0.6. To be conservative I take $\eta = 0.6$.

**Migration.** The larger is the variance of the utility shocks, the more willing individuals are to move. Therefore, $\sigma_\varepsilon$ is calibrated to reproduce the 1.99% mobility rate between the city groups. The disutility of living away from the preferred location, $\mu$, is calibrated to match the ratio of migration into unemployment to migration into employment (13% in the data).[31] This moment indicates the willingness of individuals to move into unemployment, and is likely to reflect how much they dislike to live outside their preferred locations.

Since the moving cost is identical for all workers, it is relatively cheaper for the high-skilled to move. Therefore I use the ratio of the mobility rate of the high-skilled to that of the low-skilled (1.43) to identify the moving cost $\kappa$. The calibrated moving cost is equivalent to \$8,425 (15.6% of mean annual wage earnings) in 2005 dollars.[32]

The fraction of the newborn population that has preference for living in the home location ($\nu$) is calibrated to match the mobility rate in ages 25-44. The rationale for using this moment to identify $\nu$ is that migration is higher in early ages when many workers are trying to relocate to their preferred location. Note, however, that I cannot match the migration in ages 25-44 exactly: the model produces the mobility rate of 3.49%, compared to 3.16% in the data. The reason is that in the model migration halts years before the agents leave the economy, since the benefits of moving for a short period usually do not exceed the costs. In reality individuals keep moving when old. Therefore, in order to match the overall mobility rate, my model must overpredict migration in ages 25-44 and underpredict migration in 45-64.

The distribution of workers by preferred location, $\xi_i$, is calibrated to match the observed population shares of each group of cities $i \in \{\text{LULW}, \text{HULW}, \text{LUHW}, \text{HUHW}\}$. The cross-location search friction $\Delta$ is set as follows. I take the fraction of individuals who apply for jobs in another state: 0.155 from the analysis of the Career-Builder.com data by Marinescu and Rathelot (2014). Since they only consider cross-state applications, whereas in the current paper the geographic unit of analysis is an MSA, I multiply 0.155 by 2.54, the ratio of cross-MSA to cross-state mobility in the data, and obtain $\Delta = 0.3935$. To assess the sensitivity of results to this admittedly ad-hoc way of calibrating a parameter, in Appendix B.2 I fully recalibrate the model using $\Delta = 0.3$ and $\Delta = 0.5$, and show that the results of the policy experiment described in the next session do not vary significantly with $\Delta$.

The values of the parameters $\Delta$ and $\theta_i$ (Table 2.3) imply that the probability of not receiving any job offer within 6 months ranges from 0.1% to 0.4%. Hence assuming that unemployment benefits do not expire, instead of imposing the 6-month expiration term currently in effect in the U.S., would not have a tangible effect on the quantitative results.

**Housing** I assume that the supply elasticity parameter $\zeta_i$ is the same in all cities. Blackley (1999) estimates various specification of several models of housing markets and obtains price elasticities of housing supply ranging from 1.6 to 3.7. I take the average,

[31] In the model, there are four types of migration by employment status: from employment to employment (EE), from employment to unemployment (EU), from unemployment to employment (UE), and from unemployment to unemployment (UU). The targeted moment is (EU+UU)/(EE+UE). The data counterparts of (EU+UU) and (EE+UE) are the numbers of interstate migrants who reported that the main reason for moving was "to look for work or lost job" and "new job or job transfer", respectively.

[32] This number falls in the ballpark of the existing ones, though there is no consensus on how large the moving costs are, since they are typically model-dependent. Estimates vary from 10% of mean annual labor income in Lkhagvasuren (2012), to \$34,248 in Bayer and Juessen (2012), to \$312,000 in Kennan and Walker, 2011. The average cost of a professional move is \$12,230 in 2010, according to Worldwide ERC (2015).

2.65, which corresponds to $\zeta = 1.38$. Equation (2.2.10) demonstrates that it is impossible to separately identify land areas $\Lambda_i$ and construction cost parameters $\chi_i$ within the model, since what matters for the rental price is the ratio $\Lambda_i/\chi_i^{\frac{1}{\zeta-1}}$. Hence I set $\Lambda_i = 1$ in all cities. Then I normalize the construction cost parameter for the LULW group of cities to $\chi_{\text{LULW}} = 1$, and calibrate $\chi_{\text{HULW}}$, $\chi_{\text{LUHW}}$ and $\chi_{\text{HUHW}}$ to match the rent indices in these groups relative to the LULW group. Calibrating $\Lambda_i$ and setting $\chi_i = 1$ would yield the same results. The annual housing depreciation rate is $\rho = 0.994$, following Malpezzi, Ozanne and Thibodeau (1987).

The housing preference parameters, $\gamma$ and $h_{\min}$, are calibrated jointly to match the share of housing in the expenditures of an average household and the difference in the expenditure shares between high and low skilled workers. The expenditure share is 0.24, following **?**. Using the 2005-2007 ACS data, I estimate that the fraction of earnings spent on housing by college workers is 0.74 of the fraction spent by non-college workers.

## 2.4 Relocation Subsidies

Currently, the unemployment insurance system in the U.S. does not provide incentives for workers to look for employment in other locations with potentially better job opportunities. If anything, it discourages geographic mobility, since cities with more vibrant labor markets tend to have more expensive real estate, while the unemployment benefits pay a fraction of the last paycheck and thus reflect local cost of living in the current location of an unemployed worker. As a consequence, some jobless individuals (especially those with little savings or ability to borrow) may be stuck in cities with many other unemployed workers and little hope of finding a job.[33]

Moretti (2012) proposes to augment the current unemployment insurance system in the U.S. by relocation subsidies to low-skilled unemployed workers. He argues that such a policy may reduce unemployment and the college earnings gap by allowing low-skilled workers to move to cities with better job opportunities. This proposal attracted interest of policymakers. In 2015, Congressmen Tony Cárdenas (D-CA) and Mick Mulvaney (R-SC) filed to the Congress the American Worker Mobility Act which "will create a program within the Department of Labor to provide vouchers to the long-term unemployed to relocate for the purpose of attaining or accepting employment."[34]

While Moretti's proposal sounds attractive, it has not yet been evaluated quantitatively. If relocation subsidies could indeed reduce unemployment, then by how much? How large should they be and how expensive would they be to the government? What would be their implications for the distribution of labor across cities, local wages and housing prices, and aggregate productivity? Finally, would the policy be welfare-improving? In a nutshell, the main question is: *are relocation subsidies combined with unemployment benefits a better unemployment insurance policy than the benefits alone?*

The subsidies are designed as follows. The government pays the fraction $\omega$ of the moving cost to every unemployed person who moves. In other words, the moving cost faced by an unemployed worker is $(1-\omega)\kappa$. Note that *all* unemployed workers are eligible. In Section 2.4.2, I consider alternative policies which restrict the eligibility for the subsidies to certain groups of the unemployed. Now both unemployment benefits and

[33]Carloni (2016) finds that larger unemployment benefits increase unemployed workers' geographic mobility and that the effect is stronger for more liquidity-constrained unemployed workers.

[34]https://www.congress.gov/bill/114th-congress/house-bill/2755

moving subsidies are financed by a flat-rate proportional tax $\tau$ on labor income. The tax rate must balance the budget:

$$\sum_{s=L,H}\sum_{a=1}^{T}\sum_{i=1}^{I}\left(\tau w(s,a,i)n(s,a,i)+\tau b(s,a,i)u(s,a,i)\right)=$$
$$\sum_{i=1}^{I}\sum_{j\neq i}\omega\kappa\cdot u_{\text{move}}(i,j)+\sum_{s=L,H}\sum_{a=1}^{T}\sum_{i=1}^{I}b(s,a,i)u(s,a,i), \quad (2.4.1)$$

where $u_{\text{move}}(i,j)$ is the measure of unemployed workers who move from city $i$ to city $j$.

To study the welfare properties of moving subsidies, I evaluate how the consumption of goods and the consumption of housing respond to the introduction of the subsidy. One issue with performing welfare analysis is that in the model all workers are renters. Hence, welfare analysis would only consider the utility losses of renters and ignore the gains of homeowners. Given that the homeownership rate in the U.S. is 68.6%, this would be an important omission.[35] In order to account for ownership, I redistribute 68.6% of the value of the national housing stock among all workers by adding $0.686\sum_{i=1}^{I}p_iQ_i(p_i)$ to their disposable income.

In what follows, I introduce relocation subsidies in the economy calibrated to 2005-2007, the period in which unemployment was 4.8% on average. Then, in order to check whether the effects of the subsidies differ in a recession, I recalibrate the model to 2009-2011, when unemployment was 9.3%, and introduce the subsidies.

### 2.4.1 Effects of Subsidies on Unemployment, Productivity, Welfare

The effects of moving subsidies in the economy calibrated to 2005-2007 are summarized in Table 2.6.[36] Subsidizing the moving cost stimulates migration: the mobility rate climbs from 1.99% to 2.18% when 20% of the moving cost is subsidized, and to 2.9% when 50% is subsidized. The share of migration to unemployment, i.e. relocation to search employment as opposed to relocation to accept an offer, almost doubles with the 50% subsidy, since now unemployed workers are more willing to go and look for a job in another location instead of staying put and waiting for an offer. Somewhat counterintuitively, the mobility rate of the high-skilled increases faster than that of the low-skilled. The reason is that the low-skilled wage differences across cities are small compared to the high-skilled wage differences. Hence often the wage differences are not sufficient to justify paying the high moving cost and experiencing the disutility of living outside preferred location.[37]

The subsidies reduce unemployment in 2005-2007 but the effect is small. For instance, a subsidy that pays 50% of moving expenses lowers national unemployment rate from 4.42% to 4.28%. In the booming economy of 2005-2007, the job creation rates were quite high even in the high-unemployment groups of cities. In such an environment a

[35] Data on homeownership in the U.S. can be found at http://www.census.gov/housing/hvs/index.html

[36] Under full subsidy ($\omega = 1$) the rate of geographic mobility is an abnormal 71%. This result is not surprising given that in the model job tenure does not have any value. When moving is fully paid for, workers simply jump from city to city whenever a good job offer or a positive utility shock arrives. For this reason, in most figures and tables I only show the effects of subsidies up to the 70% subsidy.

[37] This result is consistent with the finding of Amior (2015) that high-skilled workers are more geographically mobile because they experience larger surpluses from matching with firms in other locations.

worker who wants to relocate can accept any offer, save for a few periods, and then move to a better job. Thus government assistance does not have a large effect on national unemployment. The introduction of the subsidy also leads to a 0.4% increase in productivity.

The relocation subsidies appear to have a positive but tiny economic effect in the 2005-2007 period. However, in those years the economy was booming and unemployment was just 4.8%, hence one should not expect much from any policy that is aimed to cut unemployment. Hence the relocation subsidies should be also tested in a high-unemployment environment.

To address this concern, I recalibrate the job creation and destruction parameters ($\theta_i$ and $\delta$) targeting unemployment rates in the four groups of cities in 2009-2011 when the average unemployment rate was 9.3% (7.55% for my sample), and then introduce relocation subsidies in this recessionary economy.[38] Other parameters are kept as in the benchmark 2005-2007 calibration. Figure 2.3 depicts the unemployment rate in the 2005-2007 and 2009-2011 periods.

Even though I only recalibrate $\theta_i$ and $\delta$, the model matches well all moments of the economy in 2009-2011 (Table 2.5). In addition, due to high persistence of local unemployment rates and wages, 193 out of 283 metro areas retain their type in terms of above/below mean unemployment and wages as in 2005-2007. Hence I can keep the composition of the city groups as in 2005-2007, and I do not need to recalibrate the parameters that would change due to compositional changes.

The effects of moving subsidies in the recessionary years of 2009-2011 are summarized in Table 2.7. Most of the effects are larger than in 2005-2007 (Table 2.6). For instance, a subsidy that reimburses 50% of the moving cost increases the mobility rate from 2.28% to 4.15%.[39] More importantly, moving subsidies are significantly more effective in fighting unemployment in recession than in boom (Figure 2.4). In the 2009-2011 economy the 50% subsidy reduces unemployment from 7.55% to 7.19% (a 4.8% reduction), while in the 2005-2007 economy the subsidy would only reduce unemployment by 3.2%. Notably, the 0.36 percentage point reduction in 2009-2011 comes very close to the 0.45 percentage point contribution of geographic mismatch to aggregate unemployment found by Şahin, Song, Topa and Violante (2014) for the year of 2010. That is, during the Great Recession the 50% relocation subsidy would be capable of eliminating 4/5 of the geographic mismatch unemployment. Introduction of the subsidy in the recessionary period also leads to a more pronounced effect on productivity: a 1% increase in recession versus 0.4% increase in boom, for the 50% subsidy (Figure 2.5). The effect comes not only from putting more people to work, but also from the reallocation of labor to more productive cities (Figure 2.7).

Importantly, the relocation subsidy program does not increase government expenditures. The additional spending on moving subsidies is offset by the reduction in expenses on unemployment benefits, and for moderate subsidy levels the government expenditures even decrease slightly (see Figure 2.6). In particular, introduction of the 50% subsidy would reduce the expenses from 1.483% of GDP to 1.458%.[40] In other words, the sub-

[38] One reason why I only recalibrate $\theta_i$ and $\delta$ is that most other parameters are structural and should not have changed from 2005-2007 to 2009-2011.

[39] In the data, the mobility rate fell from 1.99% in 2005-2007 to 1.74% in 2009-2011. However I do not recalibrate the parameters that determine mobility, and obtain the counterfactual mobility rate of 2.28%. This discrepancy should not affect the results of the policy experiment. If anything, it downplays the role of the subsidies, since they would have a larger effect on an economy with a lower mobility rate.

[40] The actual spending on unemployment subsidies in 2009-2011 was slightly higher at 0.0166. Data

sidies put enough unemployed individuals to work so as to save the government more money on the benefits than it spends on the subsidies. However, as the subsidies go above 50% of the moving cost, workers start moving excessively which leads to a rapid increase in public spending.

Therefore, I find that unemployment benefits combined with relocation subsidies are a more effective policy tool than unemployment benefits only. The proposed policy has positive effects on unemployment and productivity, yet it does not raise government expenditures. However, it turns out that the subsidy program has very little impact on welfare (Figure 2.8, Panel b). On the one hand, the policy puts more individuals to work (extensive margin) and locates them in more productive places (intensive margin), thereby boosting productivity and consumption. On the other hand, reallocation of labor to more productive places (LUHW and HUHW groups of cities) drives up local housing prices and leads to lower aggregate consumption of housing. For instance the 50% subsidy increases the consumption of goods by 0.4%, but reduces the consumption of housing by 0.6%. Given that the share of housing in expenses of a median household in the US is 24% (**?**), this means that the policy yields nearly no effect on welfare.

One caveat with interpreting the quantitative effects of the subsidies is that the model does not allow for the externalities that a standard search-and-matching model has (Mortensen and Pissarides, 1994). The externalities arise from the fact that if a worker leaves/enters a labor market he increases/reduces the probability that other workers in the market will receive a job offer. In this situation the magnitude of the effects of relocation subsidies depends on how the negative externality in the locations that attract workers compares with the positive externality in the places that lose workers. The relative sizes of the externalities depend on the form of the matching function. In a survey of empirical studies of the matching function, Petrongolo and Pissarides (2001) find strong support for the Cobb-Douglas shape of the function, which implies that the elasticity of the matching function with respect to unemployment is constant. In this case, the positive externalities in cities that lose workers would be offset by the negative externalities in cities that gain workers, and the quantitative conclusions of the policy experiment described in this section would remain the same.

### 2.4.2 Restricted Eligibility for Subsidies

In this section I restrict the eligibility for subsidies to some groups of the unemployed and revisit the policy's effects on the economy. In the first experiment only the inhabitants of high-unemployment areas (HULW and HUHW city groups) are allowed to use the subsidy. In the second experiment the subsidy is only paid to the low-skilled workers. These alternative policy experiments are performed using the 2009-2011 calibrated economy. The government faces the same budget as in the equation (2.4.1), but now $u_{\text{move}}(i, j)$ only includes the movers eligible for the subsidy.

**Only workers from high-unemployment cities are eligible.** The effect of this policy is shown in Table 2.8. For most variables of interest, the subsidies have the same qualitative effects as in the benchmark policy but quantitatively they are smaller. In particular, a subsidy that covers 50% of moving expenses only reduces unemployment by 2.6% (compared to 4.8% when all unemployed workers are eligible) and raises productivity by 0.5% (compared to 1%). Notice that at all levels of the subsidy the effects on consumption of goods and housing are positive. Hence, when subsidies are restricted to

source: http://www.usgovernmentspending.com the residents of high-unemployment areas, welfare does improve, though the magnitude is small. Unlike in the benchmark scenario, under this policy the reallocation of workers to the high-wage cities is smaller since the inhabitants of the low-unemployment low-wage cities (the largest group, see Table 2.1) are not eligible.

**Only low-skilled workers are eligible.** One rationale for sponsoring low-skilled mobility is that high-skilled workers usually have sufficient earnings or savings to pay for their move. The effects of this policy are qualitatively identical to the effect of the benchmark policy but quantitatively are much smaller (Table 2.9). The 50% subsidy achieves worse results in terms of unemployment and productivity than the subsidy that covers all jobless workers: unemployment is only down by 1.6% and productivity is up by 0.3%. The welfare effects of this policy are much smaller than in the case when all jobless workers are eligible. As discussed above, if a low-skilled worker lives in his preferred location, he is unlikely to move somewhere else even with a subsidy. The reason is that the differences in low-skilled wages across cities are typically small, and thus are insufficient to compensate for the disutility of living outside preferred location.

## 2.5 Conclusions

Relocation subsidies have been proposed as a policy tool that helps the unemployed move to places where they are more productive or where jobs are abundant. In this paper I quantitatively evaluate the effects of moving subsidies on the economy. In order to do this, I construct a model with heterogeneous workers and multiple locations, each of which has its own labor and housing markets. Workers can move across locations but their mobility is constrained by moving expenses, cross-city search friction, as well as preferences for locations and utility shocks. I calibrate the model to the U.S. economy, and then introduce relocation subsidies that pay a fraction of the moving cost to all unemployed workers who are willing to move. The subsidies are financed by a proportional tax on labor income.

I find that a subsidy that pays 50% of the moving cost is capable of reducing unemployment by 0.36 p.p. (4.8%) and increasing productivity by 1% in the recessionary period of 2009-2011. The policy is less effective in a boom (2005-2007). Most importantly, the introduction of the subsidies keeps government expenses intact: the additional expenses on the subsidies are offset by the savings on unemployment benefits. At the same time, the policy is not welfare-improving. The subsidies attract workers to more productive places, and housing prices there increase, leading to lower average consumption of housing in these places.

The findings of this paper suggest that an unemployment insurance system that combines unemployment benefits with relocation subsidies would be more potent than the system based on unemployment benefits only. The larger effects of the policy in recession than in boom suggest that the subsidies can be used as an automatic stabilizer.

# Chapter 3

# Managers and Productivity Differences

*written jointly with Nezih Guner and Gustavo Ventura*

## 3.1 Introduction

Development accounting exercises conclude that productivity differences are central in understanding why some countries are richer than others (Klenow and Rodriguez-Clare, 1997; Prescott, 1998; Hall and Jones, 1999; Caselli, 2005). What does determine cross country productivity differences?

A growing literature emphasizes differences in management practices as a source of productivity differences; see Bloom and Van Reenen (2011) and Bloom, Sadun and Van Reenen (2016), among others. Management practices differ greatly, both across countries and across firms within a given country, and better management practices are associated with better performance (total factor productivity, profitability, survival etc.). U.S. firms on average have the best management practices, and the quality of management declines rather sharply as one moves to poorer countries.

In this paper, we present novel evidence on the earnings of managers and their relation with output per worker. We first document that age-earnings profiles of managers differ non trivially across countries. Using micro data for a set of high-income countries, we show that earnings of managers grow much faster than the earnings of individuals who have non-managerial occupations in most countries. In the United States, the earnings of managers grow by about 75% during prime working ages (between ages 25-29 to 50-54), while the earnings growth for non-managers is about 40%. This gap is weaker in other countries in our sample. In Belgium, for instance, earnings growth of managers in prime working years is about 65% whereas earnings growth of non-managers is similar to the U.S. On the other extreme, we find that in Spain the earnings of non-managers grow more than those of managers over the life-cycle.

We subsequently document that there is a strong positive relation between the relative steepness of age-earnings profiles and GDP per worker: managerial earnings grow faster than non-managerial earnings in countries with higher GDP per worker. The correlation coefficient between the log of relative earnings and log-GDP per worker is 0.49, and stable across several robustness checks on our data. Since better management practices and the GDP per worker are positively correlated in the data, there is also a very strong positive relation between the earnings growth of managers relative to the earnings growth of non managers and the quality of management practices across countries. The relation between the relative steepness of age-earnings profiles and GDP per worker remains robust when we control for individuals' educational attainment, sector of employment and self-employment status. Furthermore, these cross-country relations hold only when we look at the relative earnings growth of managers vs. non-managers (workers). There is no systematic relation between GDP per worker and the relative earnings growths of professionals (lawyers, engineers, doctors etc.) vs. workers, self-employed vs. workers, or college-educated versus non-college educated.

It is, of course, an open question how to interpret differences in managerial practices and quality across countries. In this paper, we offer a natural interpretation. Differences in managerial quality emerge from differences in *selection* into management work, along the lines of Lucas (1978), and differences in skill *investments*, as we allow for managerial abilities to change over time as managers invest in their skills. Hence, we place incentives of managers to invest in their skills and the resulting endogenous skill distribution of managers and their incomes at the center of income and productivity differences across countries.

We study a span-of-control model with a life-cycle structure along a balanced growth path. Every period, a large number of finitely-lived agents are born. These agents are heterogeneous in terms of their initial endowment of managerial skills. The objective of each agent is to maximize the lifetime utility from consumption. In the first period of their lives, agents make an irreversible decision to be either workers or managers. If an agent chooses to be a worker, her managerial skills are of no use and she earns the market wage in every period until retirement. If an agent chooses to be a manager, she can use her managerial skills to operate a plant by employing labor and capital to produce output and collect the net proceeds (after paying labor and capital) as managerial income. Moreover, managers invest resources in skill formation and, as a result, managerial skills grow over the life cycle. This implies that a manager can grow the size of her production unit and managerial income by investing a part of her current income in skill formation each period.

Skill investment decisions in the model reflect the costs (resources that have to be invested rather than being consumed) and the benefits (the future rewards associated with being endowed with better managerial skills). Since consumption goods are an input for skill investments, a lower level of aggregate productivity results in lower incentives for managers to invest in their skills. We assume that economy-wide productivity grows at a constant rate. In this scenario, we show that the model economy exhibits a balanced growth path as long as the managerial ability of successive generations grows at a constant rate.

A central component of our model is the *complementarity* between available skills and investments in the production of new managerial skills. More skilled managers at a given age invest more in their skills, which propagates and amplifies initial differences in skills over the life cycle. This allows the model to endogenously generate a concentrated distribution of managerial skills. As in equilibrium more skilled managers operate larger production units, the model has the potential to account for the highly concentrated distribution of plant size in data.

We calibrate the model to match a host of facts from the U.S. economy: macroeconomic statistics, cross sectional features of establishment data as well as the age-earnings profiles of managers. We assume for these purposes that the U.S. economy is relatively free of distortions. We find that the model can indeed capture central features of the U.S. plant size distribution, including the upper and lower tails. It also does an excellent job in generating the age-earnings profiles of managers relative to non managers that we document from data.

We then proceed to introduce size-dependent distortions as in the literature on misallocation in economic development. We model size-dependent distortions as progressive taxes on the output of a plant and do so via a simple parametric function, which was proposed originally by Benabou (2002). Size-dependent distortions have two effects in our setup. First, a standard reallocation effect, as the enactment of distortions implies that capital and labor services flow from distorted (large) to undistorted (small) production units. Second, a skill accumulation effect, as distortions affect the incentives for skill accumulation and thus, the overall distribution of managerial skills – which manifests itself in the distribution of plant level productivity. Overall, the model provides us with a natural framework to study how differences among countries in aggregate exogenous productivity and distortions can account not only for differences in output per worker but also for differences in managerial quality, size distribution of establishments and age-earnings profiles of managers. In particular, observations on the relative earnings growth of managers allows us to discipline the level of distortions.

In consistency with the facts documented above, our model implies that lower levels of economy-wide productivity result both in lower managerial ability as well as in flatter relative age-earnings profiles. A 20% decline in aggregate productivity lowers investment in skills by managers by nearly 48%, leading to a decline in the average quality of managers of about 10%. With less investment, managerial incomes grow at a slower rate over the life-cycle, generating the positive relation between output per worker and steepness of age-income profiles that we observe in the data. Lower investment by managers magnifies the effects of lower aggregate productivity, and output per worker declines by about 30%.

We then consider a menu of distortions and evaluate their effects on output, plant size, notions of productivity, and age-earnings profiles of managers. When we introduce the size-dependent distortions into the benchmark economy, we find substantial effects on output, the size distribution of plants and the relative steepness of managerial earnings. We show that such steepness is critically affected by distortions, and that distortions can eliminate all differences in the earnings growth of managers to non-managers. We find that distortions that halve the growth of relative managerial earnings (which would correspond to a move from the U.S. to Italy in our data), lead to a reduction in output per worker of about 7% – corresponding to more than half of the observed output gap between the U.S. and Italy. As a result of both misallocation and skill investment effects, managerial quality declines significantly by nearly 27%.

We find that these results are robust to the consideration of transitions between managerial and non-managerial work over the life cycle. We do this in detail in Appendix III, where we present an extension of the benchmark model with transitions between occupations.

We finally use the benchmark model to assess the combined effects of distortions and exogenous variation in economy-wide productivity. For these purposes, we force the model economy to reproduce jointly the level of output per worker in each country and the relative earnings growth of managers. We do so by choosing economy-wide productivity levels and the level of size dependency of distortions in each country to hit these two observations. We find that distortions are critical in generating relative earnings growth across countries. As a result, observations on relative earnings growth provide us with natural targets to *discipline* the level of distortions. Once we are able to reproduce both the level of GDP per worker and the relative earnings growth of managers within our model, we can assess the contribution of economy-wide productivity and distortions to cross-country differences in output per worker. To this end, we first allow economy-wide productivity to differ across countries and shut down the distortion channel, and then do the reverse (i.e. we allow distortions to vary and shut down differences in economy-wide productivity). We find that distortions alone account for about 42% of variation in GDP per worker gap with the U.S. across countries, while the rest of the variation is accounted for by differences in exogenous economy-wide productivity and interaction effects. The level of distortions that reproduce the relative earnings growth of managers in Italy (about half of the relative earnings growth in the US) are able to generate about 43% of the observed output gap with the US.

### 3.1.1 Background

The current paper builds on recent literature that studies how misallocation of resources at the micro level can lead to aggregate income and productivity differences; see Hopenhayn (2014), Restuccia and Rogerson (2013) and Restuccia (2013) for recent reviews. Following Guner, Ventura and Yi (2008) and Restuccia and Rogerson (2008), we focus in this paper on implicit, size-dependent distortions as a source of misallocation.[1] Unlike these papers, we model explicitly how distortions and economy-wide productivity differences affect managers' incentives to invest in their skills and generate an endogenous distribution of skills. As a result, we show how data on relative earnings growth of managers can be used to infer the degree of distortions within our model.

Our emphasis on age-earnings profiles of managers naturally links our paper to the empirical literature on differences in management practices – see Bloom and Van Reenen (2011), and Bloom, Lemos, Sadun, Scur and Van Reenen (2014) for recent surveys – as well as to the recent development and trade literature that considers amplification effects of productivity differences or distortions due to investments in skills and R&D. Examples of these papers are Erosa, Koreshkova and Restuccia (2010), Rubini (2011), Atkeson and Burstein (2010, 2015), Gabler and Poschke (2013), Manuelli and Seshadri (2014), and Cubas, Ravikumar and Ventura (2016), among others. Guvenen, Kuruscu and Ozkan (2014) study how progressive taxation affects the incentives to accumulate general human capital and, as a result, output for a group of high-income countries.

The importance of management and managerial quality for cross-country income differences have been emphasized by others before. Caselli and Gennaioli (2013) was possibly the first paper that highlighted the importance of managers for cross-country income differences. Caliendo and Rossi-Hansberg (2012) analyze how the internal organization of exporting firms changes in response to trade liberalization and the ensuing effects on average productivity. Gennaioli, La Porta, Lopez-de-Silanes and Shleifer (2013) build a span-of-control model of occupational choice with human capital externalities to study

[1]Other papers have dealt with explicit policies in practice. Garcia-Santana and Pijoan-Mas (2014) study examples of size-dependent policies in India, while and Garicano, Lelarge and Van Reenen (2016) and Gourio and Roys ((2014) focus on France. Buera, Kaboski and Shi (2011), Cole, Greenwood and Sanchez (2016), and Midrigan and Xu (2014) focus on the role of financial frictions in leading to misallocation of resources.

income differences across regions. Recent work by Bhattacharya, Guner, and Ventura (2013), Roys and Seshadri (2014), Akcigit, Alp and Peters (2016), and Alder (2016), among others, also study how managers and their incentives matter for aggregate productivity and the size distribution of plants and firms. Differently from these papers, we document novel facts on managerial earnings and use these facts to discipline our model economy. Our emphasis on cross–country differences in managerial earnings also relates our paper to Lagakos, Moll, Porzio, Qian and Schoellmann (2016), who study differences in experience-wage profiles across countries and show that they are flatter in poorer countries. Similar to our findings, they highlight the fact that experience-wage profiles are steeper in cognitive occupations relative to non-cognitive ones. We focus on the relation between relative earnings growth of a particular group (managers) and the GDP per capita across countries, and interpret this relation within a quantitative model.

Our paper is also connected to work that documents cross-country differences in plant and firm-level productivity and size. Hsieh and Klenow (2009), Bartelsman, Haltiwanger, and Scarpetta (2013), Hsieh and Klenow (2014) and Garcia-Santana and Ramos (2015) are examples of this line of work. Poschke (2014) builds a model of occupational choice with skill-biased change in managerial technology – managers with better skills benefit more from technological change – to account for cross-country differences in firm size distribution. Bento and Restuccia (2016) document cross-country differences in plant size in manufacturing and develop a model where distortions affect investments in plant-level productivity. In both their model and ours, distortions are amplified by endogenous investment decisions. They use this model to draw a mapping from plant size to aggregate productivity differences.

Finally, our paper is related to recent papers that emphasize the link between managerial incentives, allocation of talent and income inequality. Celik (2016) studies how income inequality can affect the allocation of talent between routine production and innovation in an overlapping generations models in which agents can spend resources productively to enhance their skills, or unproductively to create signals about their skills. More closely related to our paper, Jones and Kim (2017) study a model in which heterogeneous entrepreneurs exert effort to generate growth in their incomes and how such effort can create a Pareto-tail for top incomes.

Our paper is organized as follows. Section 3.2 documents facts on age-earnings profiles for a set of high income countries. Section 3.3 presents the model and the modeling of distortions. Section 3.4 discusses the calibration of the benchmark model. Section 3.5 presents the findings associated to the introduction of differences in exogenous economy-wide productivity and size-dependent distortions. In section 3.6, we evaluate the importance of skill investments and transitions between managerial and non-managerial work over the life cycle for our findings. Section 3.7 quantifies the relative importance of distortions vis-a-vis exogenous productivity differences in accounting for relative managerial earnings growth and output differences across countries. Finally, section 3.8 concludes.

## 3.2 Managerial Earnings over the Life Cycle

In this section, we present age-earnings profiles for managers and non-managers for a group of high-income countries. Panel data on income dynamics are available for a small set of countries and even then, since individuals with managerial occupations constitute a small group, it is not possible to construct age-earnings profiles for managers using panel data sets. As a result, we conduct our analysis with large cross-sectional data sets pertaining to different countries.

We use four data sources: The Integrated Public Use Microdata Series-USA (IPUMS-USA), IPUMS-International, Luxembourg Income Study (LIS), and the European Union Statistics on Income and Living Conditions (EU-SILC). IPUMS-International provides harmonized Census data for a large set of countries. Only few international censuses, however, contain information both on incomes and occupations. The LIS is another harmonized international data set that contains cross-sectional individual level data on income and other socioeconomic characteristics. Finally, the EU-SILC contains both cross-sectional and longitudinal microdata data for European Union countries on income, work, poverty, social exclusion and living conditions.

Our final sample consists of 20 countries: Australia, Austria, Belgium, Canada, Denmark, Finland, France, Germany, Iceland, Ireland, Israel, Italy, Luxembourg, Netherlands, Norway, Spain, Sweden, Switzerland, the United Kingdom, and the United States. Table C.1 in Appendix I shows survey years, data sources, and the number of observations for each country. Beyond data limitations, our focus on a set of high-income countries is motivated by the fact that these countries are relatively similar in their aggregate levels of schooling and hence, individuals are unlikely to differ much in terms of initial endowments of managerial ability across countries. In developing countries, factors other than managerial abilities will likely play a role in determining who is a manager and how much managers can invest in their skills. Borrowing constraints, which we abstract from in our analysis, are much more likely to be a factor in the allocation of talent in poorer countries. Likewise, selection into managerial work as well as promotions are also more likely to be affected by family and political connections.

We construct age-earnings profiles by estimating earnings equations as a function of age, controlling for year effects and educational attainment. Specifically, for each country we estimate the following regression:

$$\ln y_{it} = \alpha + \beta_1 a_{it} + \beta_2 a_{it}^2 + \gamma_t + \phi\ e_i + \varepsilon_{it}, \tag{3.2.1}$$

where $y_{it}$ is earnings and $a_{it}$ is age of individual $i$ in year $t$. The coefficients $\beta_1$ and $\beta_2$ capture the non-linear relationship between age and earnings, while $\gamma_t$ represents year fixed-effects. Finally, $e_i$ is an individual dummy variable capturing college education: it is equal to 1 if the individual has a bachelor's degree or higher, and zero otherwise. In this way we account for the fact that countries differ in the educational attainment of their population and could differ in the returns to education.[2] We estimate this equation for individuals with managerial and non-managerial occupations separately.

To estimate equation (3.2.1), we restrict the samples to ages 25 to 64, and group all ages into eight 5-year age groups: 25-29, 30-34, ..., 60-64. Individuals are classified as *managers* and *non-managers* based on their reported occupations. Table C.2 in Appendix I documents how managers are defined in different data sets. Whenever it is possible, we stick to the occupational classification by the International Labor Organization.[3] The

[2]We could allow the coefficient on the college dummy to vary over time in order to capture the possibility that skill-biased technical change affected returns to college education. For most countries in our sample, however, we have relatively small number of panels for recent years (see Table C.1 in Appendix I). As a result, allowing the coefficient on the college dummy to vary over time does not change our estimates in any significant way.

[3]An individual is classified as a manager if his/her International Standard Classification of Occupations (ISCO-88) code is 11 ("Legislators, senior officials and managers"), 12 ("Corporate Managers"),

sample is further restricted to individuals who report positive earnings and work full time (at least 30 hours per week). Earnings are defined as the sum of wage & salary income and self-employment income. Most individuals in our samples earn either wages or self-employment income. However, the samples contain a small number of managers and non-managers who report positive amounts for both types of income.

Figure 3.1 reports age-earnings profiles for managers and non-managers for the US. Managerial incomes grow by a factor of about 1.75 in prime working years – between ages 25-29 and 50-54 – whereas incomes of non-managers only rise by a factor of 1.4.[4]

Let the relative income growth, $\hat{g}$ be defined as

$$\hat{g} = \ln \left( \frac{\frac{\text{income manager, 50-54}}{\text{income manager, 25-29}}}{\frac{\text{income non manager, 50-54}}{\text{income non manager, 25-29}}} \right) \tag{3.2.2}$$

Our *key finding* is the positive relationship between GDP per worker and the life cycle growth of earnings of managers relative to the growth of non-managerial earnings.[5] We report this relationship in Figure 3.2. The slope of the fitted line is about 0.57, and the correlation is 0.49. While some readers may view these findings with caution due to small sample size, the relationship between log-GDP per worker and the steepness of managerial age-earning profiles is remarkably strong and is statistically significant at the 5% significance level.[6] Consider countries along the fitted line in Figure 3.2. GDP per worker in Italy is about 11% lower than the GDP per worker in the U.S. This is associated with an almost 50% decline in the relative earnings growth for managers ($\widehat{g}$ declines from 22% to 11%). When we go down to Sweden, GDP per worker declines by 23% from the U.S. level, while the relative earnings growth declines by about 70% ($\widehat{g}$ declines from 22% to 7%).

Since higher GDP per worker is also associated with better management practices, there is also a very strong relation between the steepness of managerial age-earning profiles and management practices. This relation is shown in Figure 3.3.[7] In countries with better management practices, such as the US or Germany, managers enjoy much higher relative earnings growth compared to managers in countries with poor management practices, such as Italy.[8]

### 3.2.1 Robustness

We next perform multiple robustness checks regarding country size, the composition of the sample and the regression equation. In all cases the relationship displayed in Figure

or 13 ("General Managers"). We do not use the more recent ISCO-08, since most of our observations are dated earlier than 2008. Source: http://www.ilo.org/public/english/bureau/stat/isco/isco88/major.htm

[4]While focusing on earnings growth during prime working years is natural, we also considered two alternative specifications. First, relative earnings of managers compared to non managers may peak at different ages in different countries. In order to check whether our results are sensitive to this feature, we found the age bracket in which the relative earnings peak in each country and used this age bracket as the reference age for computing the lifetime growth of relative income. Second, instead of using ages 50-54 as the reference age bracket, we used 60-64, and looked at the earnings growth between 25-29 and 60-64. Our main results do not change with these alternative specifications.

[5]We use the data on GDP per worker in year 2000 from Penn World Tables 7.1, Heston et al (2012)

[6]We also checked for outliers that shifted the estimated coefficient by more than one standard deviation, and we did not find any outliers with this particular metric.

[7]The relation is significant at 10% significance level.

[8]The data on management practices is from Bloom, Genakos, Sadun, and Van Reenen (2012), Table 2, and Bloom, Lemos, Sadun, Scur and Van Reenen (2014)

3.2 still holds, and in some cases it becomes even stronger.[9]

**Country Size** We first run our benchmark regression under labor-force weights to control for potential effects associated to country size. As Figure 3.4 shows, adjusting by country size does not affect our results in any significant way. The magnitude of the slope coefficient is now 0.49, with a correlation coefficient of 0.47. If we proceed even further, and remove the richest but smallest country in the data, Luxembourg, the relationship is very similar as Figure 3.5 shows.

**Detailed Education and Sector Controls** In our benchmark findings, we control only for whether an individual, manager or non manager, has college education or not. We now introduce more detailed education categories that are comparable across countries to accommodate for potential heterogeneity in earnings profiles connected with educational choices. For each country, we introduce dummies to capture whether an individual has (i) complete tertiary education, (ii) incomplete tertiary but complete secondary education, or (iii) any lower level of education, i.e. incomplete secondary, and complete or incomplete primary education. Figure 3.6 displays the findings. As the figure shows, the relationship is very similar to the benchmark one in Figure 3.2.

In addition, we control for sector of employment (both for managers and non-managers), which might interact with the different levels of educational choices. Thus, on top of the cases before, we add dummies if an individual works in the broad sectors of agriculture, manufacturing or services. The results are displayed in Figure 3.7. As the figure shows, the relationship becomes marginally stronger, with a slope coefficient of 0.59 and a correlation of 0.51.[10]

**The Role of Self Employment** To what extent do our findings depend on the assumption that some individuals have income from self employment? We answer this question in two ways. First, we exclude the self-employed from the whole sample, i.e. both from managers and non-managers, as well as only from the non-managers category. In the data, self-employed individuals are either those who state that their main source of income is self-employment, or the ones who have positive self-employment income and no wage and salary income. Many self-employed, especially those who report a non-managerial occupation, have both managerial and non-managerial duties and hence do not easily fit into our categorization. Figures 3.8 and 3.9 show that our results are robust to exclusion of all self-employed and self-employed non-managers.

Second, we narrow the definition of earnings to be wage and salary income *only*. Under this restriction, the self-employed who earn positive wage and salary income – either as managers or non-managers – are in the sample. However, their income from self-employment is not counted as part of their earnings. Figure 3.10 illustrates that dropping self-employment income from the notion of earnings only marginally changes our results. The slope coefficient is now 0.61 and the correlation 0.47.

[9]The relations in Figures 3.4-3.10 are significant at 5% significance level.

[10]Our main result also remains intact if we control for employment in the finance sector, as managerial earnings growth in this sector could arguably be much higher than in the rest of the economy.

### 3.2.2 Are Managers Different?

The main result in this section (Figure 3.2) indicates that earnings of managers grow faster relative to non-managers in richer countries. In the next section, we build a model economy in which steeper age earnings profiles of managers emerge as the result of higher investments that managers make to enhance their skills over the life-cycle in countries with either higher aggregate productivity or lower distortions. There are of course other non-managerial occupations/professions for which human capital investments over the life cycle arguably plays a key role. Do we observe a similar relation between the relative steepness of age earnings profiles and the GDP per worker for those other professions?

Figure 11 shows the findings when we replicate our exercise in Figure 3.2 for *professionals* – lawyers, engineers, doctors, etc. – since individuals in this group are likely to be more similar to managers in terms of their incentives to invest in skills.[11] We look at the earnings growth for professionals (instead of managers) relative to the earnings growth of workers – those who have non-professional, non-managerial occupations – versus GDP per worker. We find that there is no positive relation between GDP per worker and the relative earnings growth of professionals over their life-cycle. In Figure 3.12, we illustrate our findings when we repeat the same exercise for self-employed individuals – who are often used in applied work to capture the size of entrepreneurial activity in a country. Again, there is no systematic relation between the earnings growth for self employed individuals relative to workers (those who are not self-employed and have non-managerial occupations). Finally, we separate individuals in two broad categories; those with college education – four years or more of university education – and those without. Our results are illustrated in Figure 3.13. We find in this case a small, near zero, relationship between relative earnings growth and output per worker.

Overall, these results strongly suggest that forces that affect age earnings profiles of managers relative to workers/non-managers are rather specific to the incentives they face, and are unlikely to be due to factors that affect all individuals in the economy, such as non-linear income taxation. We present below a parsimonious model able to capture these key properties of the data.

## 3.3 Model

We develop a life-cycle, span-of-control model, where managers invest in their skills. Time is discrete. Each period, a cohort of heterogeneous individuals that live for $J$ periods are born. Each individual maximizes the lifetime utility from consumption, so the life-time discounted utility of an agent born at date $t$ is given by

$$\sum_{j=1}^{J} \beta^{j-1} \log(c_j(t+j-1)), \tag{3.3.1}$$

where $\beta \in (0,1)$ and $c_j(t)$ is the consumption of an age-$j$ agent at date $t$.

Each agent is born with an initial endowment of managerial ability. We denote managerial ability by $z$. We assume that initial (age-1) abilities of an agent born at date $t$ are given by $z_1(t) = G_z(t)z$, and $z$ is drawn from an exogenous distribution with cdf $F(z)$ and density $f(z)$ on $[0, z^{\max}]$. That is, individuals are heterogenous in initial managerial

[11] We define professionals as individuals who hold occupations in Group 2 in ISCO-88. Source: http://www.ilo.org/public/english/bureau/stat/isco/isco88/major.htm

ability, and abilities for newborns are shifted in each date by the factor $G_z(t)$. We assume that $G_z(t)$ grows at the constant (gross) rate $1 + g_z$.

Each agent is also endowed with one unit of time which she supplies inelastically as a manager or as a worker. In the very first period of their lives, agents must choose to be either *workers* or *managers*. This decision is irreversible. If an individual chooses to be a worker, her managerial efficiency units are foregone, and she supplies one efficiency unit of labor at each age $j$. Retirement occurs exogenously at age $J_R$. The decision problem of a worker is to choose how much to consume and save every period.

If an individual chooses instead to be a manager, she has access to a technology to produce output, which requires managerial ability in conjunction with capital and labor services. Hence, given factor prices, she decides how much labor and capital to employ every period. In addition, in every period, a manager decides how much of his/her net income to allocate towards current consumption, savings and investments in improving her/his managerial skills. Retirement for managers also occurs exogenously at age $J_R$.

We assume that each cohort is $1+g_N$ bigger than the previous one. These demographic patterns are stationary so that age-$j$ agents are a fraction $\mu_j$ of the population at any point in time. The weights are normalized to add up to one, and obey the recursion, $\mu_{j+1} = \mu_j/(1 + g_N)$.

**Technology** Each manager has access to a span-of-control technology. A plant at date $t$ comprises of a manager with ability $z$ along with labor and capital,

$$y(t) = A(t)z^{1-\gamma}\left(k^{\alpha}n^{1-\alpha}\right)^{\gamma},$$

where $\gamma$ is the span-of-control parameter and $\alpha\gamma$ is the share of capital.[12] The term $A(t)$ is productivity term that is common to all establishments, and given by $A(t) = \bar{A}\ G_A(t)$, where $G_A(t)$ grows at the (gross) rate $1 + g_A$. Thus, $\bar{A}$ controls the *level* of exogenous productivity.

Every manager can enhance her future skills by investing current income in skill accumulation. The law of motion for managerial skills for a manager who is born at period $t$ is given by

$$\begin{aligned} z_{j+1}(t+j) &= (1-\delta_z)z_j(t+j-1) + g\left(z_j(t+j-1), x_j(t+j-1), j\right) \\ &= (1-\delta_z)z_j(t+j-1) + B(j)z_j(t+j-1)^{\theta_1}x_j(t+j-1)^{\theta_2}, \end{aligned}$$

where $x_j(t)$ is goods invested in skill accumulation by a manager of age $j$ in period $t$. We assume that $\theta_1 \in (0,1)$ and $\theta_2 \in (0,1)$. $B(j)$ is the overall efficiency of investment in skills at age $j$. The skill accumulation technology described above satisfies three important properties, of which the first two follow from the functional form and the last one is an assumption. First, the technology shows complementarities between current ability and investments in next period's ability; i.e. $g_{zx} > 0$. Second, $g(z, 0, j) = 0$. That is, investments are essential to increase the stock of managerial skills. Finally, since $\theta_2 < 1$, there are diminishing returns to skill investments, i.e. $g_{xx} < 0$. Furthermore, we assume that $B(j) = (1 - \delta_\theta)B(j-1)$ with $B(1) = \theta$.

[12]In referring to production units, we use the terms *establishment* and *plant* interchangeably.

### 3.3.1 Decisions

Let factor prices be denoted by $R(t)$ and $w(t)$ for capital and labor services, respectively. Let $a_j(t)$ denote assets at age $j$ and date $t$ that pay the risk-free rate of return $r(t) = R(t) - \delta$.

**Managers** We assume that there are no borrowing constraints. As a result, factor demands and per-period managerial income (profits) are age-independent, and only depend on her ability $z$ and factor prices. The income of a manager with ability $z$ at date $t$ is given by

$$\pi(z, r, w, A, t) \equiv \max_{n,k} \{A(t) z^{1-\gamma} \left(k^{\alpha} n^{1-\alpha}\right)^{\gamma} - w(t)n - (r(t) + \delta)k\}.$$

Factor demands are given by

$$k(z, r, w, A, t) = (A(t)(1-\alpha)\gamma)^{\frac{1}{1-\gamma}} \left(\frac{\alpha}{1-\alpha}\right)^{\frac{1-\gamma(1-\alpha)}{1-\gamma}} \left(\frac{1}{r(t)+\delta}\right)^{\frac{1-\gamma(1-\alpha)}{1-\gamma}} \left(\frac{1}{w(t)}\right)^{\frac{\gamma(1-\alpha)}{1-\gamma}} z, \tag{3.3.2}$$

and

$$n(z, r, w, A, t) = (A(t)(1-\alpha)\gamma)^{\frac{1}{1-\gamma}} \left(\frac{\alpha}{1-\alpha}\right)^{\frac{\alpha\gamma}{1-\gamma}} \left(\frac{1}{r(t)+\delta}\right)^{\frac{\alpha\gamma}{1-\gamma}} \left(\frac{1}{w(t)}\right)^{\frac{1-\alpha\gamma}{1-\gamma}} z. \tag{3.3.3}$$

Substituting these into the profit function, one can show that managerial income is given by

$$\pi(z, r, w, A, t) = A(t)^{\frac{1}{1-\gamma}}\ \Omega\ \left(\frac{1}{r(t)+\delta}\right)^{\frac{\alpha\gamma}{1-\gamma}} \left(\frac{1}{w(t)}\right)^{\frac{\gamma(1-\alpha)}{1-\gamma}} z, \tag{3.3.4}$$

where $\Omega$ is a constant equal to

$$\Omega \equiv (1-\alpha)^{\frac{\gamma(1-\alpha)}{(1-\gamma)}}\ \alpha^{\frac{\gamma\alpha}{(1-\gamma)}}\ (1-\gamma)\ \gamma^{\frac{\gamma}{1-\gamma}}. \tag{3.3.5}$$

Note that since profits are linear function of managerial ability, $z$, the impact of *additional* skills on profits is independent of $z$, and a function of parameters, exogenous productivity, and prices only. Also note that given two managers, with ability levels $z$ and $z'$, we have

$$\frac{k(z', r, w, A, t)}{k(z, r, w, A, t)} = \frac{n(z', r, w, A, t)}{n(z, r, w, A, t)} = \frac{\pi(z', r, w, A, t)}{\pi(z, r, w, A, t)} = \frac{z'}{z}.$$

Hence, differences in managerial abilities map one-to-one to differences in establishments sizes and managerial incomes.

The problem of a manager is to maximize (3.3.1), subject to

$$c_j(t+j-1) + x_j(t+j-1) + a_{j+1}(t+j) = \pi(z, r, w, A, t+j-1) + (1 + r(t+j-1))a_j(t+j-1) \quad \forall\, 1 \le j \le J_R - 1, \tag{3.3.6}$$

$$c_j(t+j-1) + a_{j+1}(t+j) = (1 + r(t+j-1))a_j(t+j-1) \qquad \forall\, j \ge J_R, \tag{3.3.7}$$

and

$$z_{j+1}(t+j) = (1-\delta_z)z_j(t+j-1)+B(j)z_j(t+j-1)^{\theta_1}x_j(t+j-1)^{\theta_2} \quad \forall\, 1 \le j < J_R-1, \tag{3.3.8}$$

with $a_{J+1}(.) = 0$. The manager chooses consumption at each age, assets and investments in skill formation. For a manager who is born in period $t$ with initial managerial ability $z(t)$, let the value of lifetime discounted utility of being a manager in age 1 be $V(z(t))$.

The solution to the problem of a manager is characterized by two conditions. First, the solution for next-period assets implies a standard Euler equation for asset accumulation

$$\frac{1}{c_j(t+j-1)} = \beta(1+r(t+j))\frac{1}{c_{j+1}(t+j)}, \quad \forall\, 1 \le j < J \tag{3.3.9}$$

Second, the optimality condition for skill investments ($x$) and (3.3.9) imply the following no-arbitrage condition for investing in physical capital and skills

$$\underbrace{(1+r(t+j))}_{\text{marginal cost}} = \underbrace{\pi_z\,(t+j)\,g_x(t+j-1) + \frac{g_x(t+j-1)}{g_x(t+j)}[1+g_z(t+j)-\delta_z]}_{\text{marginal benefit}} \quad \forall\, 1 \le j < J_R-2, \tag{3.3.10}$$

For age $j = J_R - 2$, we have

$$\underbrace{(1+r(t+j))}_{\text{marginal cost}} = \underbrace{\pi_z\,(t+j)\,g_x(t+j-1)}_{\text{marginal benefit}}, \tag{3.3.11}$$

The left-hand side of equation (3.3.11) is next period's gain in income from one unit of current savings. The manager can also use this one unit as an investment on her skills. Hence, the term $g_x(.)$ on the right-hand side stands for the additional skills available next period from an additional unit of investment in the current period. The term $\pi_z(.)$ is the additional profit generated from an additional unit of managerial skills. Therefore, the right-hand side is the income again captured by the manager in his last working-age from investing one unit of the current consumption good in skill accumulation. It follows that one period before retirement, the manager must be indifferent at the margin between investing in assets and skills.

For ages less than $j = J_R - 2$, the marginal benefit incorporates an additional term as equation (3.3.10) shows. This term appears as an extra unit of investment also relaxes the skill accumulation constraint in the subsequent period.

**Workers** The problem of an age-$j$ worker is to maximize (3.3.1) by choice of consumption and assets at each age, subject to

$$c_j(t+j-1)+a_{j+1}(t+j) = w(t+j-1)+(1+r(t+j-1))a_j(t+j-1) \quad \forall\, 1 \le j \le J_R-1 \tag{3.3.12}$$

and

$$c_j(t+j-1) + a_{j+1}(t+j) = (1+r(t+j-1))a_j(t+j-1) \qquad \forall j \ge J_R, \tag{3.3.13}$$

with $a_{J+1}(.) = 0$. Like managers, workers can borrow and lend without any constraint as long as they do not die with negative assets. For an individual born period $t$, let the life-time discounted utility of being a worker at age 1 be given by $W(t)$.

**Occupational Choice** Let $z^*(t)$ be the ability level at which a 1-year old agent is indifferent between being a manager and a worker. This threshold level of $z$ is given by (as agents are born with no assets)

$$V(z^*(t)) = W(t). \tag{3.3.14}$$

Given all the assumptions made, $V$ is a continuous and a strictly increasing function of $z$. Therefore, (3.3.14) has a well-defined solution, $z^*(t)$, for all $t$.

### 3.3.2 Balanced Growth

We focus from now on the *balanced growth* scenario. In this case, the rate of return to assets and the fraction of managers are constant, and all variables grow in the long run at specified rates, driven ultimately by the two sources of growth in the environment: exogenous productivity growth and exogenous growth in the managerial skills of newborns. In Appendix 2, we show that our economy has a balanced growth path if and only if initial skills growth takes place at a given rate. We show therein that the growth rate in output per person ($g$) along the balanced growth path is given by

$$1 + g = (1 + g_A)^{\psi},$$

where $\psi$

$$\psi \equiv \frac{1-\theta_1}{\gamma(1-\alpha) + (1-\theta_2)(1-\gamma) - \theta_1(1-\alpha\gamma)}.$$

### 3.3.3 Equilibrium

We outline now what constitutes an equilibrium for an economy in the stationary case, i.e. along a balanced growth path. We normalize variables to account for stationary growth. Define the growth factor $D(t) \equiv (1 + g)^t$. Hence, we normalize variables wage rates, managerial income, individual consumption, asset holdings and factor demands by $D(t)$, and denote normalized variables by the " ˆ " symbol (i.e. $\hat{a}_j = a_j(t)/D(t)$). Regarding managerial abilities, recall that managerial ability levels of members of each new cohort are given by $z_1(t) = \tilde{z}(t)z$, with a common component that grows over time at the rate $g_z$, and a random draw, $z$, distributed with cdf $F(z)$ and density $f(z)$ on $[0, z^{\max}]$. Hence, the normalized component is simply $z$ for each individual. After the age-1, and given the stationary threshold value $z^*$, the distribution of managerial abilities is endogenous as it depends on investment decisions of managers over their life-cycle.

Let managerial abilities take values in set $\mathcal{Z} = [z^*, \overline{z}]$ with the endogenous upper bound $\overline{z}$. Similarly, let $\mathcal{A} = [0, \overline{a}]$ denote the possible asset levels. Let $\psi_j(\hat{a}, z)$ be the mass of age-$j$ agents with assets $\hat{a}$ and skill level $z$. Given $\psi_j(\hat{a}, z)$, let

$$f_j(z) = \int \psi_j(\hat{a}, z) d\hat{a},$$

be the skill distribution for age-$j$ agents. Note that $f_1(z) = f(z)$ by construction.

Each period those agents whose initial ability is above $z^*$ work as managers, whereas the rest are workers. Then, in a stationary equilibrium with given prices, $(r, \hat{w})$, labor, capital and goods markets must clear. The labor market equilibrium condition can be written as

$$\sum_{j=1}^{J_R-1} \mu_j \int_{z^*}^{\overline{z}} \hat{n}(z, r, \hat{w}, \bar{A}) f_j(z) dz = F(z^*) \sum_{j=1}^{J_R-1} \mu_j \tag{3.3.15}$$

where $\mu_j$ is the total mass of cohort $j$. The left-hand side is the labor demand from $J_R - 1$ different cohorts of managers. A manager with ability level $z$ demands $\hat{n}(z, r, \hat{w}, \bar{A})$ units of labor and there are $f_j(z)$ of these agents. The right-hand side is the fraction of each cohort employed as workers. Let $\hat{L}$ denote the size of normalized, aggregate labor in stationary equilibrium.

In the capital market, the demand for capital services must equal the aggregate value of the capital stock. Hence,

$$\sum_{j=1}^{J_R-1} \mu_j \int_{z^*}^{\overline{z}} \hat{k}(z, r, \hat{w}, \bar{A}) f_j(z) dz = \hat{K} \tag{3.3.16}$$

where $\hat{K}$ is the normalized, per person stock of capital and $\hat{k}(z, r, \hat{w}, \bar{A})$ is capital demand from a manager with ability $z$. The goods market equilibrium condition requires that the sum of undepreciated capital stock and aggregate output produced in all plants in the economy is equal to the sum of aggregate consumption and savings across all cohorts plus skill investments by all managers across all cohorts.

**Discussion** We now discuss a few properties of the model economy that are of importance for our subsequent analysis. First, it is worth noting that managerial investments are essential for the model to reproduce the facts on managerial earnings documented in section 3.2. In the absence of investments, initial managerial ability depreciates and managerial earnings would decline over the life cycle. This stands in contrast with the evidence documented for the United States and other countries, where earnings of managers relative to non managers grow substantially with age.

Second, our environment offers a natural notion of aggregate *managerial quality*, or total managerial skills per manager, $\hat{Z}$. Formally,

$$\hat{Z} \equiv \frac{\sum_{j=1}^{J_R-1} \mu_j \int_{z^*}^{\overline{z}} z f_j(z) dz}{\hat{M}}, \tag{3.3.17}$$

where $\hat{M}$ is the number of managers in equilibrium. Hence, changes in managerial quality in response to changes in the environment are determined by changes in the number of managers (i.e. changes in $z^*$), as well as by changes in the distribution of skills. That is, changes in the incentives to accumulate managerial skills will naturally induce changes in managerial quality. Even if the threshold $z^*$ is unchanged in response to a change in the environment, the mass of individuals at each level of managerial ability over the life cycle will change as individuals optimally adjust their skill accumulation plans.

Finally, our model of production at heterogenous units aggregates into an production function. It is possible to show that aggregate output can be written as

$$\hat{Y} = \bar{A} \ \hat{Z}^{1-\gamma} \ \hat{M}^{1-\gamma} \ \hat{K}^{\gamma\alpha} \hat{L}^{\gamma(1-\alpha)} \tag{3.3.18}$$

As we discuss in next sections, changes in occupational decisions across steady-state equilibria affect output in different ways. On the one hand, a reduction in $z^*$ raises the number of managers but reduces the size of aggregate labor in equation (3.3.18). On the other hand, a reduction in $z^*$ reduces the magnitude of managerial quality as defined above since marginal managers are less able than inframarginal ones. As we show next, the resulting managerial quality changes can be quantitatively large in response to policy-induced occupational shifts.

### 3.3.4 Size-Dependent Distortions

Consider now the stationary environment in which managers face distortions to operate production plants. We model these distortions as size-dependent output taxes. In particular, we assume an establishment with output $y$ faces an average tax rate $T(y) = 1-\lambda y^{-\tau}$. This tax function, initially proposed by Benabou (2002), has a very intuitive interpretation: when $\tau = 0$, distortions are the same for all establishments and they all face an output tax of $(1-\lambda)$. For $\tau > 0$, the distortions are size-dependent, i.e. larger establishments face higher distortions than smaller ones. Hence, $\tau$ controls how dependent on size the distortions are.[13]

With distortions, profits are given by

$$\pi(z,\hat{r},\hat{w},\bar{A}) = \max_{n,k}\{\underbrace{\lambda\bar{A}^{1-\tau}z^{(1-\gamma)(1-\tau)}\left(k^{\alpha}n^{1-\alpha}\right)^{\gamma(1-\tau)}}_{\text{after-tax output}} - \hat{w}n - (\hat{r}+\delta)k\}$$

From the first order conditions, the factor demands are now given by

$$\begin{aligned} n(z,\hat{r},\hat{w},\bar{A}) &= \left[\lambda\bar{A}^{1-\tau}\gamma(1-\alpha)(1-\tau)\right]^{\frac{1}{1-\gamma(1-\tau)}} \times \\ &\times \left(\frac{1}{\hat{r}+\delta}\right)^{\frac{\gamma\alpha(1-\tau)}{1-\gamma(1-\tau)}} \left(\frac{\alpha}{1-\alpha}\right)^{\frac{\gamma\alpha(1-\tau)}{1-\gamma(1-\tau)}} \left(\frac{1}{\hat{w}}\right)^{\frac{1-\gamma\alpha(1-\tau)}{1-\gamma(1-\tau)}} z^{\frac{(1-\gamma)(1-\tau)}{1-\gamma(1-\tau)}}, \end{aligned} \tag{3.3.19}$$

and

$$\begin{aligned} k(z,\hat{r},\hat{w},\bar{A}) &= \left[\lambda\bar{A}^{1-\tau}\gamma(1-\alpha)(1-\tau)\right]^{\frac{1}{1-\gamma(1-\tau)}} \times \\ &\times \left(\frac{1}{r+\delta}\right)^{\frac{1-\gamma(1-\alpha)(1-\tau)}{1-\gamma(1-\tau)}} \left(\frac{\alpha}{1-\alpha}\right)^{\frac{1-\gamma(1-\alpha)(1-\tau)}{1-\gamma(1-\tau)}} \left(\frac{1}{\hat{w}}\right)^{\frac{\gamma(1-\alpha)(1-\tau)}{1-\gamma(1-\tau)}} z^{\frac{(1-\gamma)(1-\tau)}{1-\gamma(1-\tau)}}. \end{aligned} \tag{3.3.20}$$

Using the factor demands 3.3.19 and 3.3.20, we can write the profit function as

$$\pi(z,\hat{r},\hat{w},\bar{A}) = \left(\lambda\bar{A}^{1-\tau}\right)^{\frac{1}{1-\gamma(1-\tau)}}\widetilde{\Omega}\left(\frac{1}{\hat{r}+\delta}\right)^{\frac{\alpha\gamma}{1-\gamma}}\left(\frac{1}{\hat{w}}\right)^{\frac{\gamma(1-\alpha)}{1-\gamma}} z^{\frac{(1-\gamma)(1-\tau)}{1-\gamma(1-\tau)}} \tag{3.3.21}$$

where

$$\widetilde{\Omega} \equiv (1-\gamma(1-\tau))\,\alpha^{\frac{\gamma\alpha(1-\tau)}{1-\gamma(1-\tau)}}\,(1-\alpha)^{\frac{\gamma(1-\alpha)(1-\tau)}{1-\gamma(1-\tau)}}\,(\gamma\,(1-\tau))^{\frac{\gamma(1-\tau)}{1-\gamma(1-\tau)}}.$$

[13]This specification has been recently used by Bauer and Rodriguez-Mora (2014) and Bento and Restuccia (2016) in the development literature. In a public-finance context, this specification has been used by Heathcote, Storesletten and Violante (2016) and Guner, Lopez-Daneri and Ventura (2016), among others, to analyze the effects of income tax progressivity.

Note that for any $z$ and $z'$, we now have

$$\frac{k(z',\hat{r},\hat{w},\bar{A})}{k(z,\hat{r},\hat{w},\bar{A})} = \frac{n(z',\hat{r},\hat{w},\bar{A})}{n(z,\hat{r},\hat{w},\bar{A})} = \frac{\pi(z',\hat{r},\hat{w},\bar{A})}{\pi(z,\hat{r},\hat{w},\bar{A})} = \left(\frac{z'}{z}\right)^{\frac{(1-\gamma)(1-\tau)}{1-\gamma(1-\tau)}},$$

where

$$\frac{(1-\gamma)(1-\tau)}{1-\gamma(1-\tau)} < 1,$$

as long as $\tau > 0$. That is, for a *given* distribution of managerial abilities, size-dependent distortions produce a more compressed size distribution of establishments and managerial incomes.

Similarly, for any $z$ and $z'$ the optimal skill investment is now characterized by

$$\frac{x'_j}{x_j} = \left(\frac{z'_j}{z_j}\right)^{\left(\theta_1 - \frac{\tau}{1-\gamma(1-\tau)}\right)\frac{1}{1-\theta_2}}.$$

It is easy to show that the exponent in the expression is decreasing with respect to the parameter $\tau$ governing size dependency. Hence, size-dependent distortions also reduce incentives of higher-ability managers to invest in their skills.

## 3.4 Parameter Values

We assume that the U.S. economy is free of distortions, and calibrate the benchmark model parameters to match aggregate and plant-size moments as well as moments on managerial incomes from the U.S. data. In particular, we force our economy to reproduce the earnings of managers relative to non-managers over the life cycle estimated in section 3.2. We divide our discussion of parameter choices between parameters that are set directly from data and those that are inferred so the model reproduce data moments in equilibrium.

**Data and Parametric Assumptions** For observations on the U.S. plant sizes, we use the 2004 U.S. Economic Census. The average plant size is about 17.9 employees, and the distribution of employment across plants is quite skewed. About 72.5% of plants in the economy employ less than 10 workers, but account for only 15% of the total employment. On the other hand, less than 2.7% of plants employ more than 100 employees but account for about 46% of total employment. From our findings in section 3.2, managerial incomes (relative to non-managers) grow by about 18% between ages 25-29 to 40-44 – $\hat{g}$ value equal to 16.8% – and by about 25% by ages 60-64 – $\hat{g}$ value equal to 22.1%.

We note that a measure of capital and output consistent with the current model on business plants should include capital and output accounted for by the business sector. The measure of capital and output discussed in Guner et al (2008) is consistent with the current plant size distribution model. Hence, we use the value of capital output ratio and the capital share reported in that paper. These values are 2.325 (at the annual level) and 0.326, respectively, with a corresponding investment to output ratio of about 0.178 for the period 1960-2000.

We assume that the exogenous skills of newborn individuals follow a log normal distribution. Specifically, we assume that $\log(z_1)$ is normally distributed with mean normalized to zero ($\mu_z = 0$) and variance $\sigma_z^2$. We let the model period correspond to 5 years. Each cohort of agents enters the model at age 25 and lives until 79 years old. Agents retire at age 65. Hence, in the model agents live for 11 periods; 8 as workers or managers and 3 as retirees.

**Parameters Set Directly from Data** Based on our notion of output accounted for by the business sector for the period 1960-2000, we set the annual growth rate of output per worker ($g$) to 2.6% as in Guner et al (2008), with a corresponding annual population growth rate ($g_N$) of 1.1%. For our notion of capital and output, given a capital output ratio and an investment ratio, our (stationary) law of motion of capital implies a depreciation rate ($\delta$) of about 4% at the annual level. We also infer directly the depreciation rate of managerial skills ($\delta_z$) from the data on managerial earnings. Since the theory predicts no skill investments at the end of the life cycle, the depreciation rate can be inferred from the observed decline in earnings of managers between ages 55-59 to 60-64. We estimate $\delta_z$ to be 4.8% at the annual level.

**Parameters Set in Model Equilibrium** At the aggregate level, we want the benchmark model to be consistent with the capital output ratio in the U.S. economy. At the cross sectional level, the model implied distribution of plants should capture some of the important features of the U.S. plant size distribution discussed in the beginning of this section. At the same time, our model should generate age-earning profiles of managers relative to non managers that are consistent with the data. Therefore we jointly calibrate the remaining parameters, $\{\alpha, \gamma, \sigma_z, \beta, \theta, \theta_1, \theta_2\}$, to match the following moments: mean plant size, the fraction of plants with less than 10 workers, the fraction of plants with 100 workers or more, the fraction of the labor force employed in plants with 100 or more employees, the growth of managerial incomes relative to those of non-managers between ages 25-29 and 40-44, the growth of managerial incomes relative to those of non-managers between ages 25-29 to 60-64, and the aggregate capital-output ratio.[14] Note that since the capital share in the model is given by $\gamma\alpha$, and since this value has to be equal to the data counterpart (0.326), a calibrated value for $\gamma$ determines $\alpha$ as well.

The resulting parameter values are displayed in Table 3.1. Table 3.2 shows the targeted moments together with their model counterparts as well as the entire plant size distribution.

**Skill Investments** In our calibration, the fraction of resources that are invested in skill accumulation is about 0.9% of GDP. Despite the relatively small fraction of resources devoted to the improvement of managerial skills, the incomes of managers grow significantly with age in line with data. Figure 3.14 shows that the earnings of managers relative to non managers in the model are in conformity with the data. It is important to emphasize that managerial skill investments play a central role in the growth of earnings. If we halve the value of the parameter $\theta_2$ that governs the incentives to invest goods in

[14]Within our framework, since each plant has one manager, targeting mean plant size determines a fraction of managers. Finding an empirical target for the fraction of managers (workers) is not straightforward. In contrast to he model economy, each plant in the data might have several managers in different layers and hierarchies. In the benchmark economy, about 5.3% of population are managers, which would be the fraction of managers if we assume that each plant is run by a single manager in the data. In the benchmark data used in Section 2 under the classification for cross-country purposes, about 10% of workforce are managers in the United States. Further restrictions on who is a manager in the data makes the fraction of managers smaller, and easily less than the value implied by our model.

skill formation, we find that resources invested in skill accumulation drop to about 0.6% of output and the earnings growth of managers relative to non managers between ages 25-29 and 60-64 ($\hat{g}$) drops from the benchmark value of 22% to 10%.

It is also important to mention that the benchmark model is able to replicate the properties of the entire plant size distribution fairly well, as demonstrated in Table 3.2. In particular, the model is able to generate the concentration of employment in very large plants. Again, skill accumulation plays an important role in this case. We calculate that if we give managers the skills they are born with for their entire life cycle (i.e. skill formation is not allowed), the mean plant size drops from 17.7 to about 15.7, and the share of employment accounted for by large plants (100 employees and higher) drops from 46% to 37.8%. In similar fashion, if we alternatively halve the value of $\theta_2$, as above, this share drops to 36.2% and the mean size drops to about 15.7 employees. Hence, data moments on the size distribution of plants and age-earnings profiles allow us to pin down parameters on the production technology, $\gamma$, and the skill accumulation, $\{\sigma_z, \theta, \delta_z, \theta_1, \theta_2\}$, while $\beta$ is determined mainly by the capital-output ratio.

## 3.5 Findings

In this section, we present and discuss the central quantitative findings of the paper. We first explore the implied responses of our model economy to variations in economy-wide productivity. Subsequently, we introduce distortions as described in section 3.3.4 and quantify their importance. Finally, we evaluate the relative importance of each channel in accounting for differences in relative earnings growth and output across countries.

### 3.5.1 Variation in Economy-wide Productivity

We now consider the effects of changes in economy-wide productivity levels; the term $\overline{A}$ that is common to all establishments. Two main reasons motivate our exercises. First, it is of interest to understand the extent to which variation in economy-wide productivity can affect variation in relative earnings growth across countries. If variation in this variable can account for observed output gaps across countries, can it also account for observed differences in the life-cycle earnings growth of managers relative to non managers? Second, there is substantial variation in the size of establishments across countries that is correlated to the level of development.[15] If productivity differences affect the accumulation of managerial skills, they can also contribute to cross-country differences in establishment size.

Table 3.3 shows our results when we lower economy-wide productivity, or productivity for short, relative to the benchmark economy across steady states. We consider three levels of productivity alongside the benchmark value; $\overline{A} = \{0.9, 0.8, 0.7\}$. Not surprisingly, exogenous reductions in productivity lead to substantial reductions in output across steady states. When $\overline{A}$ is lowered by 10%, 20% and 30%, output declines by about 15.5%, 29.8% and 43.1%, respectively. This follows from the standard effects of lower productivity across the board, in conjunction with the lower accumulation of managerial skills over the life cycle emphasized here. In this regard, Table 3.3 shows that investment

[15] The size of production establishments is strongly associated with output levels across countries. Bhattacharya (2010) documents such differences in establishment size for selected countries. Bento and Restuccia (2016) uncover large size differences between rich and poor countries in the manufacturing sector.

in managerial skills drops from about 0.9% of output to about 0.6% when economy-wide productivity drops by 30%.

As a result of lower investment in managerial skills, relative age-earnings profiles become *flatter* as Table 3.3 demonstrates. A reduction in economy-wide productivity of 20% translates into a reduction of more than half in the earnings growth of managers relative to non managers. Relative earnings growth can even turn negative for low values of economy-wide productivity. Therefore, the model has the potential to generate the positive relation between GDP per worker and the steepness of age-earnings profiles documented in section 3.2 (see Figure 3.2).

It is worth relating these results to properties of standard span-of-control models. First, managerial skills are simply endowments in models of that class. Thus, in a life-cycle context, such models cannot account for the relative earnings facts documented in section 3.2. Second, the same forces that lead to changes in the steepness of relative managerial profiles lead also to equilibrium changes in plant size. Changes in exogenous productivity, as modeled here, do *not* generate size differences in a growth model with a Lucas (1978) span-of-control technology, as changing $\bar{A}$ has no effect on occupational decisions.[16] The consequences of changing aggregate productivity, however, are different in the current setup. As productivity drops, both wage rates and managerial rents drop as in the standard span-of-control model. But a productivity drop also reduces the marginal benefit associated to an extra unit of income invested in skill accumulation (see equations 3.3.10 and 3.3.11). As a result, managerial skills become overall lower, which translates into further reductions in labor demand and therefore, on the wage rate. The net result is a reduction in the value of becoming a worker relative to a manager at the start of life, which leads in turn to an increase in the number of managers. Quantitatively, however, these size effects are moderate as Table 3.3 demonstrates.

Finally, Table 3.3 shows that aggregate managerial quality drops alongside reductions in economy-wide productivity: a reduction in $\bar{A}$ of 30% translates into a reduction in managerial quality of more than 15%. Again, this occurs due to the presence of investments in managerial skills. Lower managerial quality follows from the (small) increase in the number of managers across steady states, in conjunction with lower investments in managerial skills in response to a reduction in economy-wide productivity – see equation (3.3.17).

**Output and Earnings Growth Differences** Given the results in Table 3.3, it is natural to ask the extent to which the model can reproduce the relation between GDP per worker and the relative earnings growth for managers that we observe in the data. To this end, for each of the countries in our data, we select a value of $\overline{A}$ such that our model economy reproduces GDP per worker of that country relative to the U.S. We keep all other parameters fixed at their benchmark values.

We find that the model predicts a weaker relationship between output and the relative earnings growth of managers over the life cycle than it is observed in the data. While in the data the slope coefficient between these variables is about 0.57, our model predicts a value of about 0.39. In other words, there is more variation in relative earnings growth in the data that what our model predicts exclusively via changes in economy-wide productivity. Output changes driven by changes in economy-wide productivity are not accompanied, however, by corresponding reductions in relative earnings growth as observed in the data.

[16] This requires a Cobb-Douglas specification as we assume in this paper.

As a result, the variance in $\hat{g}$ implied by the model is just about 11% of the variance of this variable in the data.

### 3.5.2 Size-Dependent Distortions

We now study the quantitative role of size-dependent distortions via the implicit tax function $T(y) = 1 - \lambda y^{-\tau}$, as explained in section 3.3.4. The key in this formulation is the curvature parameter $\tau$ governing the degree of size dependency; if $\tau > 0$, the plants with higher output levels face higher marginal and average rates, while if $\tau = 0$, implicit taxes are the same for all, regardless of the level of output.

We evaluate the consequences across steady states of an array of values for the parameter $\tau$ in Table 3.4, under $\lambda = 1$. For each value of $\tau$, Table 3.4 also reports the implied distortion wedge, measured as the take home rate, $1- T(y)$, evaluated at 5 times the mean output. As Table 3.4 demonstrates, the effects of size-dependent distortions can be dramatic on some variables. Introducing size-dependent distortions leads to a reduction in output across steady states, an increase in the number of managers (reduction of plant size), and to a reallocation of output and employment to smaller production units. In the context of the current setup, these effects are concomitant with less investment in managerial skills and thus, with less steep age-earnings profiles of managers relative to non-managers. This occurs as with the introduction of distortions that are size dependent, large establishments reduce their demand for capital and labor services relatively more than smaller ones, leading to a reduction in the wage rate. This prompts the emergence of smaller production units, as individuals with low initial managerial ability become managers. This is the mechanism highlighted in Guner et al (2008) and others. In addition, investment in skills decline in the current setup reinforcing the equilibrium effects on output, size and managerial quality.

**The Quantitative Importance of Distortions** How large are the distortions imposed by different levels of $\tau$? To answer this question, we calculate the distortions borne by large plants at high multiples of mean output levels *relative* to those at mean output.[17] From this perspective, we find that distortions do not increase too much with output. For instance, the distorting factor at five times mean output amounts to 0.97, 0.94, and 0.91, for values of $\tau$ of 0.02, 0.04 and 0.06, respectively. That is, in all cases the distorting factors differ by less than ten percentage points.

Quantitatively, raising size dependency from zero to $\tau = 0.02$ leads to a reduction in output of about 7.1%, a reduction in mean size from 17.7 to 13.2 employees, and to a sizable reduction in managerial quality of about 26.7%. The effect on the relative earnings growth of managers is substantial, with a reduction in the slope coefficient ($\hat{g}$) to less than half the benchmark value. Indeed, as Table 3.4 shows, it is possible to eliminate all growth in relative managerial earnings over the life cycle! A value of $\tau = 0.06$ leads to a negative slope coefficient. Such change is accompanied by a drop in output of about 18.7%, and by a drastic reduction in managerial quality of about 54.4%.

It is worth noting that the concentration of employment at large establishments drops significantly with distortions. About 46% of employment is accounted for by plants with 100 employees or more in the benchmark economy. This figure drops sharply as the size

[17]Specifically, we calculate the ratio of one minus the marginal rate on plants at $q$ times mean output relative to mean output. Since one minus the marginal tax rate amounts to $(1 - \tau)\lambda y^{-\tau}$, this ratio effectively amounts to $q^{-\tau}$.

dependency of distortions becomes more important. At $\tau = 0.02$, the share of employment in large establishments is 34% while at $\tau = 0.06$, this variable falls to less than half of its benchmark value. The behavior of the employment at large establishments in response to distortions, like other key variables, is closely connected to the importance of skill investments for our findings. We quantify the role of skill investments for our findings in section 3.6.

How do our findings relate to the data presented in section 3.2? Table 3.4 shows that a level of distortions associated to $\tau = 0.02$ leads to a decline in the relative earnings growth of managers comparable to the level of Italy, as documented in section 3.2. Italy's gap in terms of output per worker is of about 11% in relation to the United States in the data. Thus, from this perspective, size-dependent distortions alone can account for more than half of Italy's output gap (7% vs. 11%). Overall, size-dependent distortions can generate substantial reductions in the relative earnings growth of managers and can also lead to sizable output losses.

Several papers in the literature, e.g. Poschke (2014), Garcia-Santana and Ramos (2015) and Bento and Restuccia (2016), provide evidence on how mean establishment size differs across countries. Establishments tend to be smaller in poorer economies and with a higher level of distortions. The results in this section imply that size-dependent distortions lower both the mean establishment size and the relative earnings growth of managers. Among European countries, countries like Germany and France have steeper relative profiles for managers (as documented in Section 2) and also larger establishments, while countries like Italy and Spain have flatter profiles and smaller establishments.[18]

## 3.6 Discussion

We present below two sets of exercises to highlight the quantitative role of different aspects of our model. First, we investigate the extent to which transitions between managerial and non-managerial work matter for our quantitative results. Second, we evaluate the quantitative importance of investments in managerial skills.

### 3.6.1 Occupational Transitions over the Life Cycle

We have so far considered a model abstraction where each individual chooses his/her occupation, whether to be a worker or a manager, at the start of his/her life and this decision is *irreversible*. Thus, our abstraction assumes away potential transitions between non-managerial and managerial work. We ask: is this omission quantitatively important?

To address this question, we first document facts on transitions between managerial and non-managerial occupations in U.S. data. We subsequently build and calibrate a model economy that allows agents to switch between occupations, and evaluate whether our conclusions on the effects of exogenous productivity changes and distortions are robust

[18] We calculate that for a set of 15 European countries the correlation between mean size and the relative earnings growth of managers is about 0.38. The size data for European countries is provided by Eurostat (http://ec.europa.eu/eurostat/web/structural-business-statistics/entrepreneurship/business-demography). The unit of observation in European data is an *enterprise*, which can have more than one production unit and thus, it falls somewhere between a firm and a plant. Mean enterprise size is about 12 and 14 workers in France and Germany, respectively versus about 7 and 6 workers in Spain and Italy (the numbers include enterprises with zero of employees).

to occupational switches. We present the model and analysis in detail in Appendix III.[19]

We find that as the result of occupational switches, the fraction of managers grows in the first half of the life cycle, and then remains roughly constant until retirement. Nonetheless, our model – parameterized to capture the changes in the number of managers over the life cycle – predicts that the effects of exogenous productivity changes and distortions on the variables of interest is remarkably similar to the effects we found under the simpler benchmark model benchmark. We then conclude that for the questions addressed in this paper, a richer model that accommodates transitions between managerial and non-managerial occupations is not essential.

### 3.6.2 The Importance of Skill Investments

We now attempt to quantify the importance of the novel channel emphasized in this paper – managerial skill investments – for a host of variables of interest. We ask: how large is the amplification role of such investments in response to size-dependent distortions and exogenous reductions in productivity? We answer this question via two different variations of our model economy. We first consider the case when managerial investments are not allowed, but individuals are endowed with the same age-profile managerial skills over the life cycle as in the benchmark economy. We dub this scenario *Fixed Lifetime Skills*. In the second case, skill investments are also shut down but individuals are endowed with their initial skill endowment at each age. We dub this scenario *Fixed Initial Skills.*[20] We concentrate our analysis in two special values of distortions and productivity; $\tau = 0.02$ and $\bar{A} = 0.9$. These values are close to the average values in our cross-country analysis in section 3.7.

**Distortions** Our findings are summarized in Table 3.5 for key variables; output, mean size, managerial quality and the employment share in large (100+) establishments. We find that managerial skill formation accounts for about one fourth (24-27%) of changes in output when size-dependent distortions are introduced. This is a significant finding, for investments in skill formation are less than 1% of output in the benchmark economy.

For size statistics, the message is somewhat different; managerial skill formation accounts for a smaller fraction of the changes predicted by the benchmark model when distortions are introduced. For mean size, skill formation accounts for about 9% of the changes under fixed lifetime skills and nearly 19% under the fixed initial skills scenario. For the share of employment at large establishments, skill formation accounts for about 24% of the changes under fixed lifetime skills and nearly 15% under the fixed initial skills scenario. All these suggest that the economic forces behind a standard span-of-control model tend to dominate for predicted changes in size statistics.

We find that skill formation has a substantial role upon the predicted changes in managerial quality. Table 3.5 indicates that about 25%-35% of changes in this variable can be accounted for by changes in the skills of managers across steady states. In understanding this finding, recall from our discussion in section 3.3.3 that changes in this variable is affected by the number of managers across steady states as well as by changes in the skill

[19] Our alternative model extends our benchmark with three key modifications. First, we allow for investments in managerial skills by managers and non managers. Second, skill investments are risky as in Huggett, Ventura and Yaron (2011). Third, we allow for occupational switches over the life cycle.

[20] For each scenario, we compute a steady state in the absence of distortions and under $\bar{A} = 1$. We use these steady states as the basis for our quantification of the importance of skill investments.

distribution of managers. Thus, while there are large changes in the number of managers due to size-dependent distortions, the ensuing changes in the incentives to accumulate skills lead to substantial effects on managerial quality.

**Economy-wide Productivity** Unlike the findings for distortions, the contribution of managerial skill formation to changes in output driven by productivity changes is relatively small (between 6% and 8%). Thus, the bulk of changes in this variable across steady states in this case are due to standard forces; the direct impact of changes in productivity on output plus the indirect effects via capital accumulation.

For the rest of the variables in Table 3.5, our analysis establishes that managerial skill formation accounts for all changes across steady states. This is expected. As mentioned earlier, under a span-of-control model with exogenous managerial skills, exogenous changes in productivity lead to no changes in the plant-size distribution and therefore, on managerial quality. Hence, it follows that any change in these variables in response to productivity changes is driven by the associated changes in managerial skills.

## 3.7 Accounting for Cross-Country Differences

We investigated in previous sections the extent to which exogenous variation in productivity and in size-dependent distortions affect several variables of interest. We now concentrate on the role of these two exogenous sources of variation for the facts documented in section 3.2. We ask: what is the contribution of cross-country differences in exogenous productivity versus distortions in accounting for differences in output per worker and relative earnings growth? To answer this question, we perform a straightforward exercise. We select values for productivity ($\bar{A}$) and distortions ($\tau$) for each country to reproduce (i) output per worker levels, and (ii) relative earnings growth ($\hat{g}$). That is, we select parameters to reproduce, as well as we can, the position of each country in Figure 3.2.[21] We then eliminate each of the cross-country differences separately, and evaluate the quantitative role of each source of cross-country variation. The average of calibrated values of $\bar{A}$ is 0.978 across 20 countries in the sample (recall that for the U.S., $\bar{A} = 1$) and the average of calibrated values of $\tau$ is 0.028 (recall that for the U.S. $\tau = 0$). The average value for $\tau$ implies a wedge, $[1 - T(5\overline{y})] / [1 - T(\overline{y})]$, of 0.96, i.e. a manager that produces five times the mean output faces an average and marginal distortion (implicit tax) that is four percentage points higher.[22]

Consider first differences in $\overline{A}$, i.e. keep $\overline{A}$ at its calibrated value for each country and set $\tau = 0$. Figure 3.15 shows the model-implied and the actual relation between GDP per worker and the relative earnings growth of managers. In line with our previous findings, we find that when we only allow for differences in $\bar{A}$, the model predicts a weaker relationship between output and the relative earnings growth of managers over the life

[21] In Figure 3.2, relative earnings growth for managers is negative for four countries (Finland, Iceland, Spain and Denmark). The model has difficulty to generate negative relative earnings growth observed in the data. The calibration exercise, nonetheless, is able to match the remaining 16 countries exactly.

[22] The combinations of $\overline{A}$ and $\tau$ that replicate the data differ non trivially across countries. Countries like Belgium, Italy or Sweden are assigned low $\overline{A}$ values and positive $\tau$'s to account for the fact that they have lower output per worker and lower income growth of their managers compared to the US. On the other hand, the model assigns low $\overline{A}$ values and negative $\tau$'s (i.e. distortions decline by size) to be able to match the data for countries like Germany, France or Switzerland where relative earnings profiles are similar or steeper than they are in the U.S.

cycle. In particular, while variation in $\bar{A}$ is able to generate significant differences in output per worker, the variation in relative earnings growth is more muted than in the data. As a result, while in the data the slope coefficient between these variables is about 0.57, our model predicts a value of about 0.39 – around the same value as in section 3.5.1.

Turning into the role of distortions, what happens if we keep $\tau$ at its calibrated value for each country and set $\overline{A} = 1$? Figure 3.16 shows the results of this exercise. The slope coefficient between relative earnings growth and log GDP per worker is now about 0.96, much higher than the value in the in the data (0.57). That is, in contrast to the case of variation in $\bar{A}$, the model predicts a stronger relationship between log-output per worker and $\hat{g}$ than in the data. Indeed, the correlation between data and model-implied relative earnings growth is about 0.90. In other words, we find that size-dependent distortions are *critical* to generate the observed variation in cross-country relative earnings growth of managers.

This exercise allows us to calculate the GDP per worker gap between each country and the U.S. that can be accounted by differences in $\overline{A}$ and $\tau$. To this end, we compute GDP per worker in the model when keeping $\tau$ at its calibrated values and setting $\overline{A} = 1$ (the U.S. value), and then calculate the implied output gap with the US and compare it with the same gap in the data. These calculations, for example, imply that about 43% of the output gap between Italy and the U.S. can be accounted for by differences in $\tau$. For Sweden, the equivalent figure is 18%. Repeating the same exercise for other countries, we find that differences in distortions account on average for about 42% of the output per worker gaps with the U.S. in our data. The rest is accounted by differences in economy-wide productivity and interaction effects.

### 3.7.1 Discussion: The Role of Initial Managerial Ability

In the previous section, we look for country-specific values of aggregate productivity ($\bar{A}$) and distortions ($\tau$) that can produce the observed cross-country differences in the data. We do this by following the standard practice in the literature and changing only these two parameters, while keeping all other parameters at their benchmark values. It is of course understood that there are other possible differences across countries. The analysis, in particular, assumes that the initial skill distribution is same across countries. Recall that we assume $\log(z_1)$ is normally distributed with mean normalized to zero ($\mu_z = 0$) and variance $\sigma_z^2$. A natural question is how differences in initial skill distributions would affect our results.

To answer this question, we consider two economies: one in which the mean of the initial skill distribution is 20% lower and another one in which its coefficient of variation is 20% higher.[23] Table 3.6 shows the results. Consider first an economy with a lower mean for $z_1$. Since the economy is populated with workers which have lower initial skills, output and the average managerial quality decline by 7% and 14%, respectively. On the other hand, relative earnings growth ($\hat{g}$) increases, but not by much. Managers who

[23] If $\log(z_1)$ is normally distributed with $\mu_z$ and $\sigma_z$, the mean and the CV of $z_1$ are given by $e^{\mu_z + \frac{1}{2}\sigma_z^2}$ and $\sqrt{e^{\sigma_z^2} - 1}$, respectively. In the first experiment we simply lower $\mu_z$ (and keep $\sigma_z$ the same) so that the mean is 20% lower, while in the second experiment we increase $\sigma_z$ so that the CV is 20% higher (and lower $\mu_z$ so that the mean remains the same). In terms of other distribution of skills across a more diverse set of countries, these changes are quite substantial. For instance, the mean math PISA score in the USA is only about 15% higher than in Mexico. Similarly, the coefficient of variation is about the same in the US and Mexico, and only about 10% in Brazil. See Cubas et al (2016) for an analysis.

start with relatively low level of skills invest more aggressively (as a share of GDP), and their earnings grow faster than they do in the benchmark economy. In equilibrium, in an economy with lower average skills there are fewer managers and more workers (given all other parameters fixed). Also, the wage is lower which contributes to a higher growth in managerial incomes and to a larger firm size. A higher CV of the skill distribution, in contrast, has essentially no effect on aggregate output. Relative earnings growth and plant size are higher, but again the effects are quantitatively small. This is not surprising, as a longer right tail of the skill distribution results in a larger pool of super-star managers who operate larger plants.

Overall, the results in Table 3.6, while informative about the forces in our model, indicate that even large differences in the initial skill distributions are not likely to generate significant differences in output per worker and relative earnings growth of managers across countries.

## 3.8 Concluding Remarks

We document that across a group of high-income countries, the mean earnings of managers tend to grow faster than for non managers over the life cycle, and that the earnings growth of managers relative to non managers over the life cycle is positively correlated with output per worker. To interpret these facts, we develop an equilibrium, span-of-control model in which managers invest in their skills. Thus, the incentives of managers to invest in their skills are central in determining the growth of their earnings over the life cycle. As a result, our model predicts endogenous differences in managerial quality across countries driven by *selection* – who becomes a manager – and by *investments* in managerial skills. We discipline this model with a host of observations on managerial earnings, the size-distribution of plants in the United States and macroeconomic aggregates.

We introduce and quantify the importance of aggregate productivity differences, and size-dependent distortions as emphasized by the misallocation literature. We find that distortions that halve the growth of relative managerial earnings over the life cycle – the hypothetical case of Italy in our data – reduce output by 7%. This is more than a half of the observed output gap between the US and Italy.

Our findings also show that distortions are responsible for the bulk of differences in the relative earnings growth of managers over the life cycle across countries in our data. As a result, observations on relative earnings growth can be used as natural targets to discipline the level of distortions. In a decomposition exercise, we find that cross-country variation in distortions – estimated to create observed cross-country differences in relative earnings growth – can account for about 42% of the cross-country variation in output per worker with the U.S.

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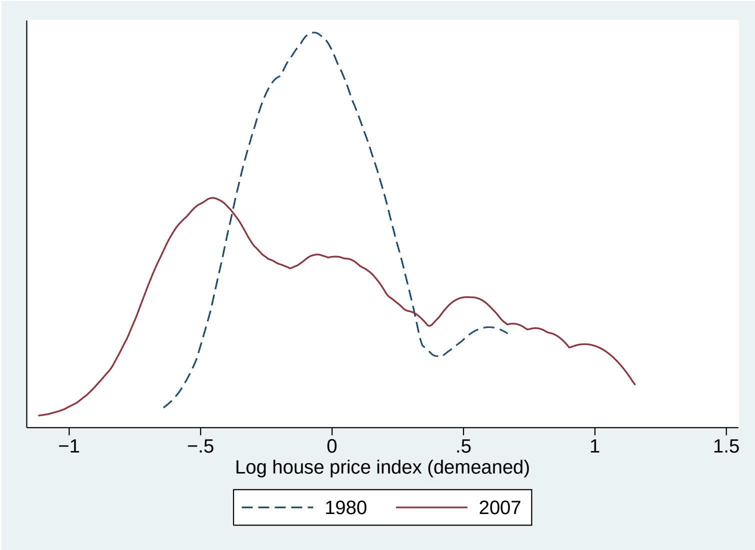
# Tables and Figures for Chapter 1

Table 1.1: Summary statistics

| | 1980 | 2007 |
|---|---|---|
| *Labor markets:* | | |
| Mean hourly wage, $ | 8.48 | 26.18 |
| Log college wage gap | 0.368 | 0.609 |
| Variance of log wages | 0.0085 | 0.0167 |
| Fraction of college graduates, % | 25.5 | 39.8 |
| *Housing markets:* | | |
| Mean house price index, $'000 | 51.7 | 244.1 |
| Mean rent index | 168 | 681 |
| Variance of log prices | 0.062 | 0.221 |
| Variance of log rents | 0.055 | 0.057 |
| Fraction of homeowners, % | 70.9 | 72.5 |
| Expenses on housing, % income | 0.192 | 0.199 |

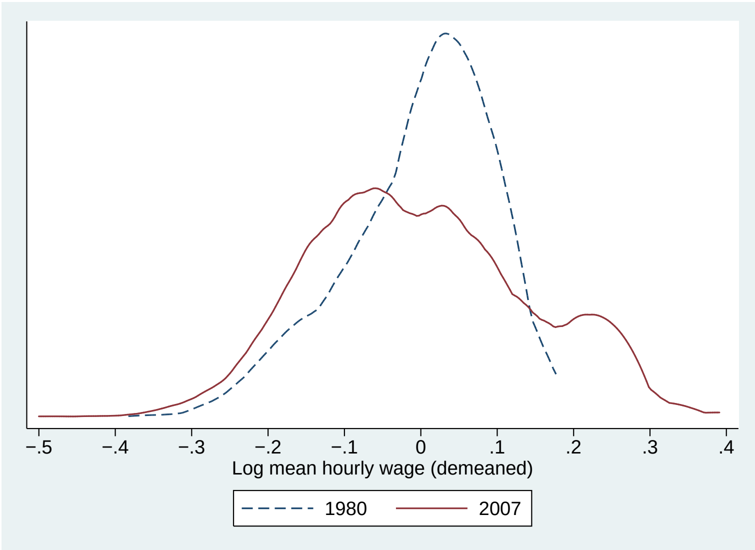
*Note:* The table compares summary statistics for labor and housing markets in 1980 and 2007 in the sample of 190 metropolitan areas used in this paper. See Section 1.2.2 for details.

Figure 1.1: Dispersion of house prices across MSAs



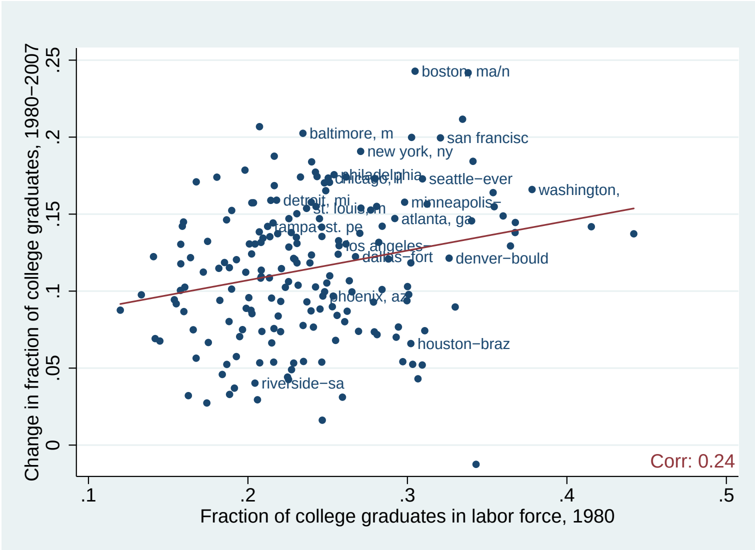

*Note:* The figure plots the population-weighted distribution of log quality-adjusted house prices across metropolitan areas in years 1980 and 2007. The adjustment for quality is conducted by means of a hedonic regression, as in Eeckhout, Pinheiro and Schmidheiny (2014). The distribution is smoothed using a Epanechnikov kernel. See Section 1.2.2 for details.

Figure 1.2: Dispersion of wages across MSAs



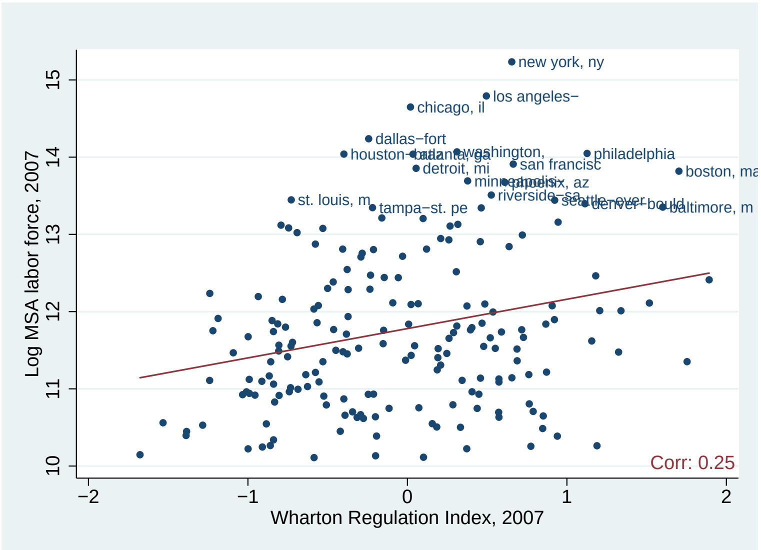

*Note:* The figure plots the population-weighted distribution of log average hourly wages across metropolitan areas. The distribution is smoothed using a Epanechnikov kernel. See Section 1.2.2 for details.

Figure 1.3: Skill sorting




*Note:* The figure plots the relationship between the share of college graduates in a metro area's labor force in 1980 and the change in the share between 1980 and 2007. See Section 1.2.2 for details.

Figure 1.4: Regulation and city size

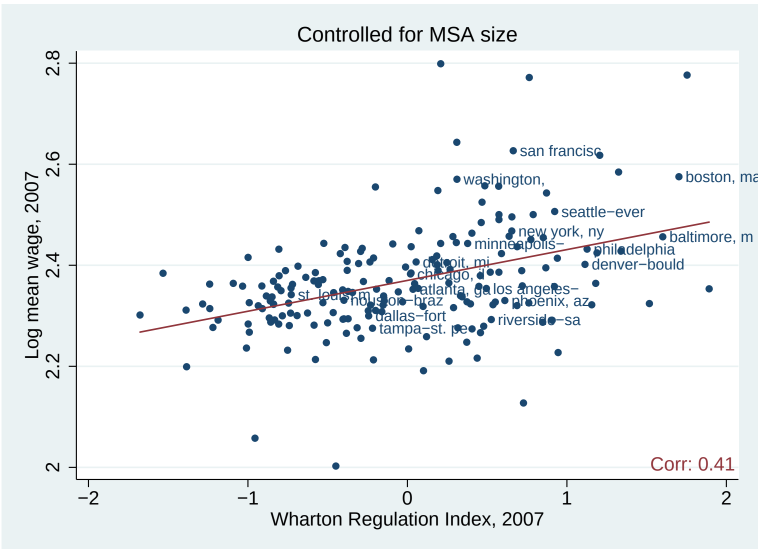



*Note:* The figure plots the relationship between a metro area's labor force and the Wharton Residential Land Use Regulatory Index. See Section 1.2.2 for details.

Figure 1.5: Regulation and population density

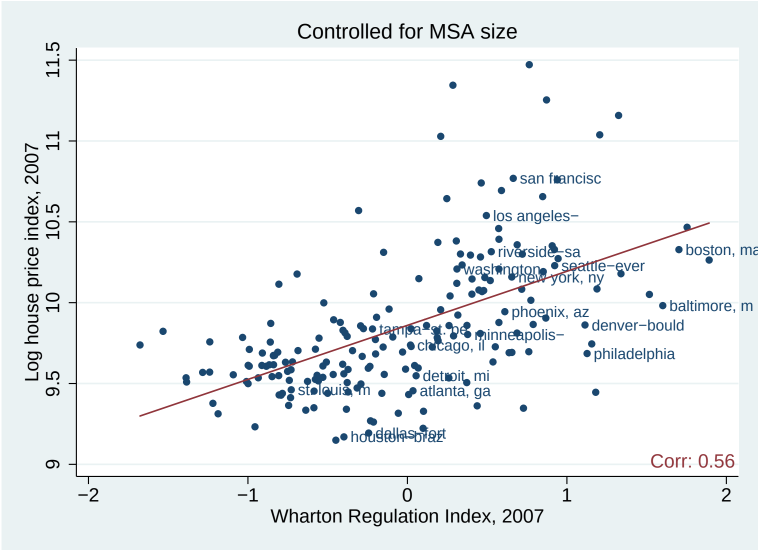

*Note:* The figure plots the relationship between city population density and the Wharton Residential Land Use Regulatory Index. Population density is measured as labor force per sq km of an MSA land area. The land area is the fraction of land within a 50km radius from the population centroid of a metropolitan area that is not occupied by water or slopes above 15%, taken from Saiz (2010). See Section 1.2.2 for details.

Figure 1.6: Regulation and wages



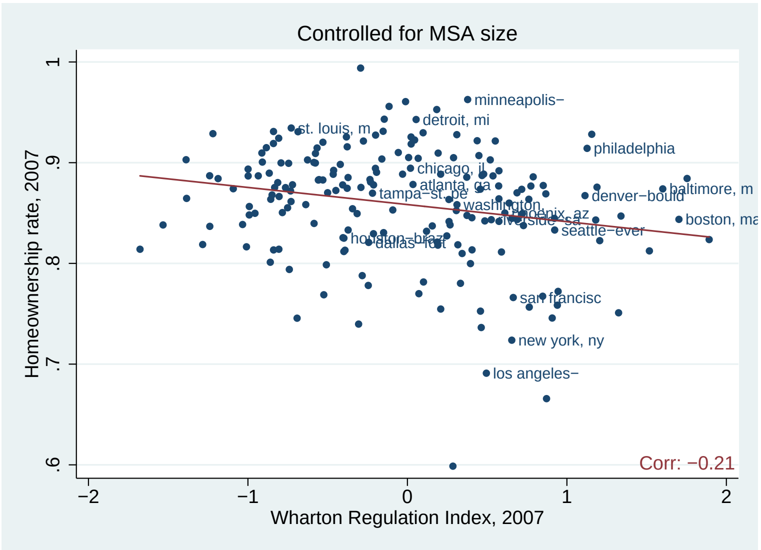

*Note:* The figure plots the relationship between mean hourly wage, controlled for workforce size, and the Wharton Index. See Section 1.2.2 for details.

Figure 1.7: Regulation and house prices



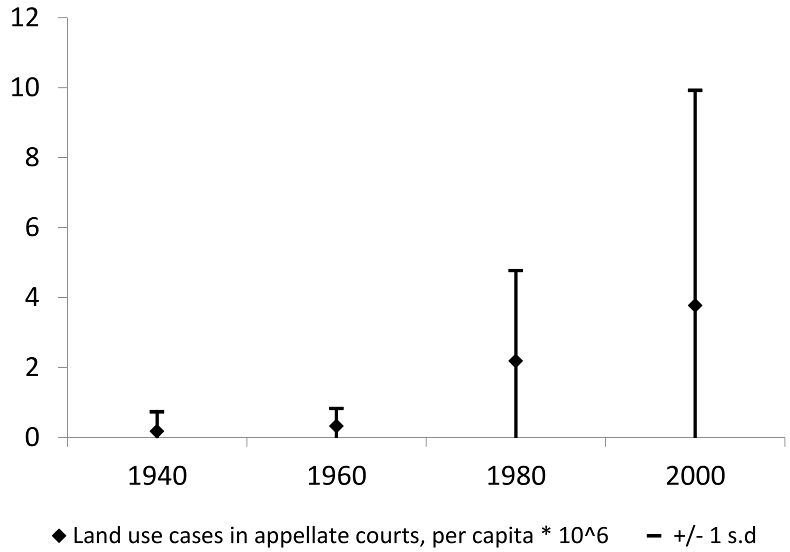

*Note:* The figure plots the relationship between the quality-adjusted house price index, controlled for workforce size, and the Wharton Index. See Section 1.2.2 for details.

Figure 1.8: Regulation and homeownership




*Note:* The figure plots the relationship between the mean homeownership rate, controlled for workforce size, and the Wharton Index. See Section 1.2.2 for details.

Figure 1.9: Rise in regulation and increasing differences across locations




*Note:* The figure plots the average and -/+ one standard deviation across U.S. states of the regulation index constructed by Ganong and Shoag (2015). This figure is adapted from Table 1 of their paper.

Table 1.2: Predictors of Local Political Pressure Index

| | LPPI |
|---|---|
| College share, 2005-2007 | 2.321 |
| | (0.724) |
| Log mean wage, 2005-2007 | -0.957 |
| | (0.520) |
| Log mean house prices, 2005-2007 | 0.338 |
| | (0.123) |
| Land availability (Saiz, 2010) | 0.451 |
| | (0.204) |
| Votes for democratic candidate in state, 2008 | -0.423 |
| | (0.386) |
| Constant | -1.937 |
| | (1.237) |
| R2 | 0.12 |
| N | 187 |

*Note:* The table lists coefficients of a regression of the metropolitan area's Local Political Pressure Index (part of the Wharton Index) on college share, wages, house prices, land availability (from Saiz (2010)), and share of votes for the Democratic candidate in 2008 presidential elections in the state where the metro area is located. Standard errors are in parentheses. See Section 1.4.4 for details.

Table 1.3: Model Parameters

| **Parameter** | | | **Source** |
|---|---|---|---|
| *Production* | | | |
| Productivity shifters | $g_{msa}$ | multiple | Estimate labor demand equation |
| Substitution between skills | $\eta$ | 0.682 | Estimate labor demand equation |
| Capital share | $\alpha$ | 0.335 | Valentinyi and Herrendorf (2008) |
| *Housing* | | | |
| Construction cost | $\chi^O$ | 15,040 | Calibrate. Target: exp share on housing |
| Elasticity of price wrt density | $\bar{\zeta}$ | 0.1093 | Estimate housing supply equation |
| Elasticity of price wrt regulation | $\tilde{\zeta}^{\text{reg}}$ | 0.0666 | Estimate housing supply equation |
| Land | $\Lambda_m$ | multiple | Data (Saiz, 2010) |
| Downpayment | $\delta$ | 0.2 | Data. 20% of house price |
| Per-period mortgage payment | $\mu$ | 0.1333 | 80%/6 |
| Mortgage term | $\pi$ | 6 | Data. 30 years |
| Mortgage interest rate | $i_h$ | 0.0621 | Data |
| *Workers and preferences* | | | |
| Distribution of skills | $\lambda_H$ | 0.3984 | Data |
| Home attachment | $\xi$ | 6.52 | Calibrate. Target: inter-MSA mig, 20-29 |
| Distr. of preferences for cities | $\psi_m$ | many | Calibrate. Target: distr. of labor force |
| Annual discount factor | $\beta$ | 0.96 | |
| Utility of homeownership | $\gamma$ | 0.62 | Calibrate. Target: homeownership rate |
| *Regulation* | | | |
| Campgn contribution function | $\omega_0$ | 2.66E+07 | Calibrate. Target: mean WRLURI |
| Campgn contribution function | $\omega_1$ | 3.34 | Calibrate. Target: p75/p50 WRLURI |
| Avg influence of homeowners | $\bar{\phi}^O$ | 15.71 | Calibrate. Target: s.d. WRLURI |
| Avg influence of renters | $\bar{\phi}^R$ | 1.00 | Normalization |

*Note:* The table shows parameter values and whether they are estimated, calibrated, or taken from the literature. See Section 1.4 for details.

Table 1.4: Model Fit (targeted moments)

| | **Model** | **Data** |
|---|---|---|
| Expenditures on housing (fraction of income) | 0.21 | 0.20 |
| Homeownership rate | 0.73 | 0.73 |
| Mean regulation | 0.070 | 0.070 |
| S.d. regulation | 0.016 | 0.017 |
| p75/p50 regulation | 1.18 | 1.17 |
| Inter-MSA mobility, ages 20-29 | 0.36 | 0.36 |
| Population (corr: data vs model) | 0.99 | |

*Note:* The table displays the targeted moments in the data and their counterparts in the model. See Section 1.4 for details.

Table 1.5: Model Fit (non-targeted moments)

| | **Model** | **Data** |
|---|---|---|
| Dispersion of wages across MSAs (var of log) | 0.016 | 0.017 |
| Dispersion of house prices across MSAs (var of log) | 0.141 | 0.221 |
| Mean house price, $000 | 277 | 244 |
| Expenditures on housing, high/low skilled | 0.70 | 0.72 |
| Homeownership rate, high/low skilled | 1.20 | 1.22 |

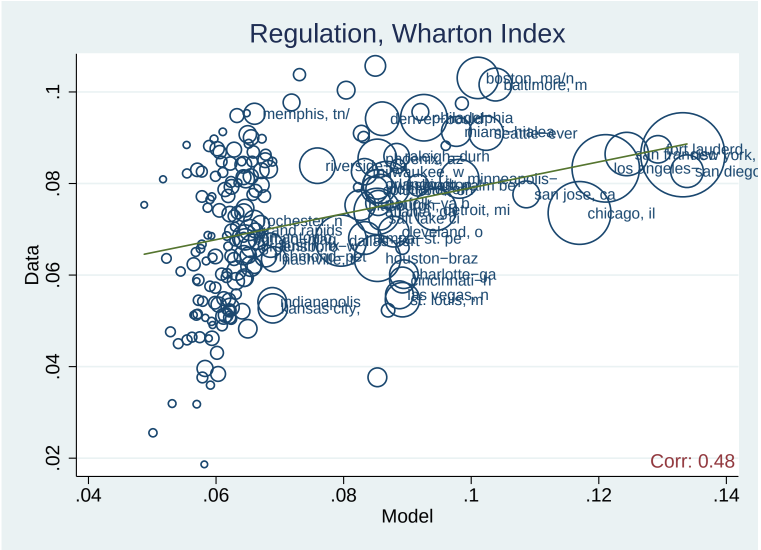
*Note:* The table displays some non-targeted moments in the data and their counterparts in the model. See Section 1.4 for details.

Table 1.6: Correlations: model vs data

| | **Correlation** |
|---|---|
| Regulation (Wharton Index) | 0.48 |
| Regulation (Approval Delay Index, part of the Wharton Index) | 0.68 |
| Homeownership rate | 0.76 |
| College share | 0.75 |
| House prices | 0.76 |

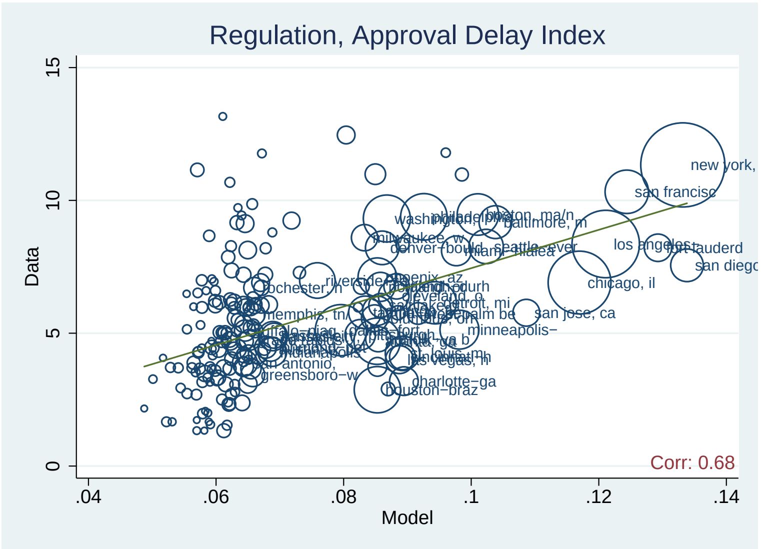
*Note:* The table displays correlations between MSA-level outcomes observed in the data and the outcomes produced by the model. The correlations are weighted by metro area's workforce size. See Section 1.4 for details.

Figure 1.10: Regulation: model vs data. Wharton Index



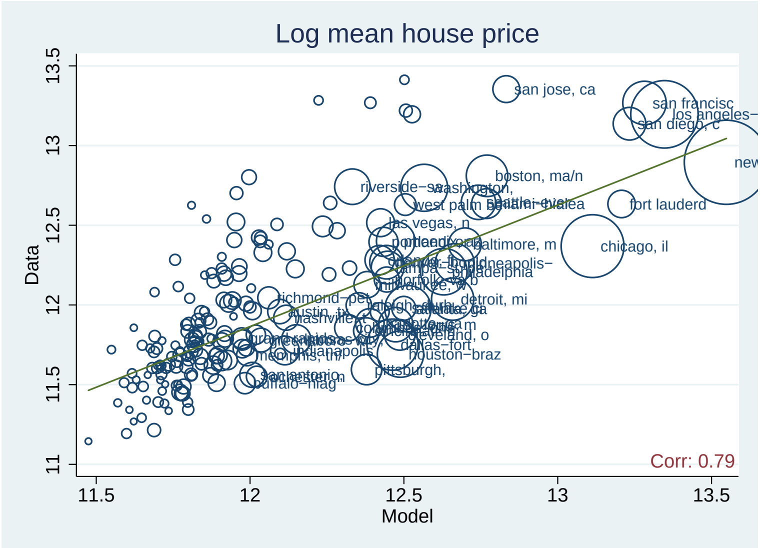

*Note:* The figure depicts the relationship between the observed level of regulation (Wharton Index) and the level predicted by the model. The fitted line is weighted by workforce size. See Section 1.5 for details.

Figure 1.11: Regulation: model vs data. Approval Delay Index



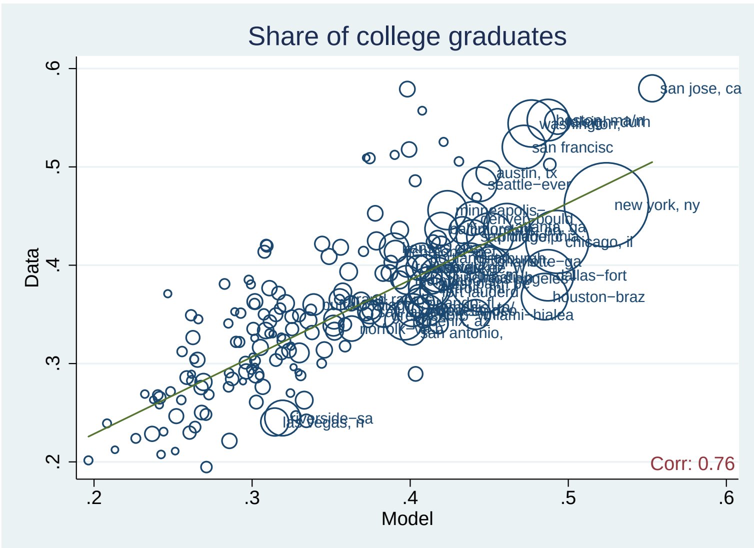

*Note:* The figure depicts the relationship between the observed level of regulation (Approval Delay Index, part of the Wharton Index) and the level predicted by the model. The fitted line is weighted by workforce size. See Section 1.5 for details.

Figure 1.12: House prices: model vs data




*Note:* The figure depicts the relationship between the observed level of the quality-adjusted house price index and the house prices predicted by the model. The fitted line is weighted by workforce size. See Section 1.5 for details.

Figure 1.13: Fraction of college graduates: model vs data




*Note:* The figure depicts the relationship between the observed share of high-skilled workers in the data (college graduates and above) and the share predicted by the model. The fitted line is weighted by workforce size. See Section 1.5 for details.

Table 1.7: Most regulated MSAs (top 10 out of 190)

| | # model | # data |
|---|---|---|
| San Diego, CA | 1 | 50 |
| New York, NY-NJ-CT-PA | 2 | 34 |
| Fort Lauderdale, FL | 3 | 28 |
| San Francisco, CA | 4 | 32 |
| Los Angeles, CA | 5 | 46 |
| Chicago, IL | 6 | 90 |
| San Jose, CA | 7 | 73 |
| Baltimore, MD | 8 | 4 |
| Seattle, WA | 9 | 16 |
| Boston, MA-NH | 10 | 3 |

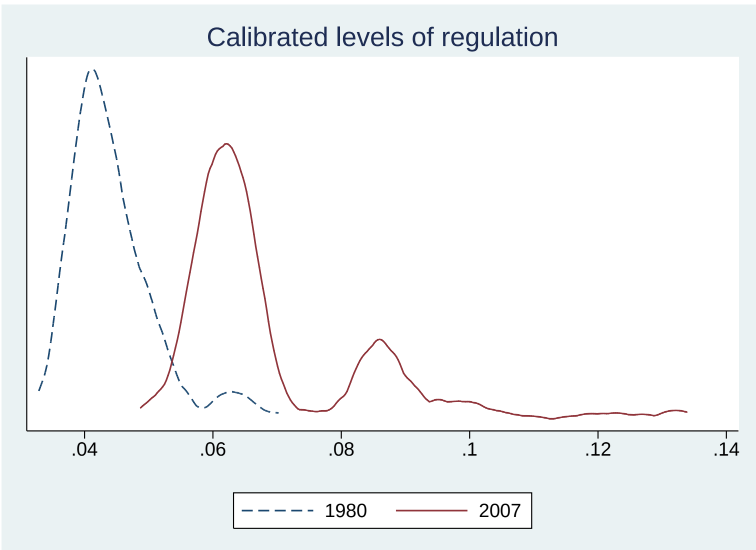
*Note:* The table shows the ten most regulated metropolitan areas in the model and their corresponding rank in the data, according to the Wharton Index. See Section 1.4 for details.

Table 1.8: Static effects of regulation

| | Benchmark | Equal reg | Half reg | Zero reg |
|---|---|---|---|---|
| Mean regulation | 0.070 | 0.082 | 0.034 | 0.000 |
| S.d. regulation | 0.016 | 0.000 | 0.007 | 0.000 |
| Output | 1.000 | 1.021 | 1.019 | 1.024 |
| Mean wages | 1.000 | 1.020 | 1.019 | 1.024 |
| Variance of log wages | 0.0162 | 0.0150 | 0.0147 | 0.0139 |
| Mean house prices | 1.000 | 0.891 | 0.533 | 0.273 |
| Variance of log house prices | 0.141 | 0.046 | 0.070 | 0.021 |

*Note:* This table shows the results of a quantitative experiment in which the distribution of regulation levels is changed exogenously. The column "Benchmark" shows moments from the benchmark 2007 calibration. The column "Equal reg" shows moments from the 2007 economy in which regulation in all MSAs is set to the weighted mean level, 0.082. The column "Half reg" displays moments from the 2007 economy in which in all cities regulation is half the benchmark level. The column "Zero reg" shows moments from the 2007 economy in which regulation is set to zero everywhere. See Section 1.5.1 for details.

Figure 1.14: Calibrated regulation




*Note:* The figure plots the Epanechnikov kernel-smoothed distribution of levels of regulation in the benchmark 2007 calibration and the 1980 levels imputed using the model. See Section 1.6 for details.

Table 1.9: Model fit, 1980 calibration

| | **Model** | **Data** |
|---|---|---|
| *Targeted moments* | | |
| Expenditures on housing (fraction of income) | 0.19 | 0.20 |
| Homeownership rate | 0.73 | 0.71 |
| *Non-targeted moments* | | |
| Mean regulation | 0.044 | — |
| S.d. regulation | 0.007 | — |
| p75/p50 regulation | 1.10 | — |
| Inter-MSA mobility, ages 20-29 | 0.31 | — |
| Dispersion of wages across MSAs (var of log) | 0.010 | 0.011 |
| Dispersion of house prices across MSAs (var of log) | 0.049 | 0.062 |
| Mean house price, $000 | 83.3 | 51.7 |

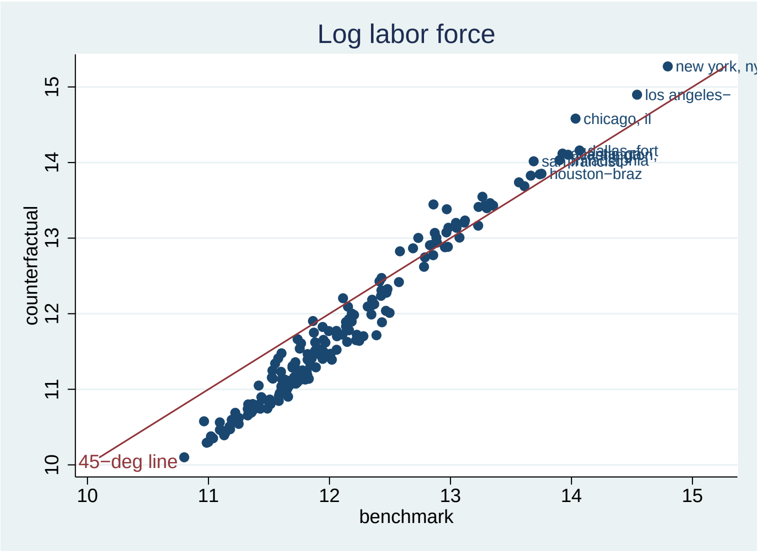
*Note:* The table displays targeted and some non-targeted moments in the data and their counterparts in the model for the 1980 calibration. See Section 1.4 for details.

Table 1.10: Effects of the rise in regulation from 1980 to 2007

| | 1980 benchmark | 2007 benchmark | 2007 counterfact | Contrib |
|---|---|---|---|---|
| Output | 1.000 | 4.834 | 4.933 | 2.1% |
| Mean wages, $'000 | 19.6 | 57.8 | 59.0 | 2.0% |
| Variance of log wages | 0.0098 | 0.0162 | 0.0147 | -23.5% |
| Mean house prices, $'000 | 83.3 | 277.2 | 157.0 | -43.4% |
| Variance of log house prices | 0.049 | 0.141 | 0.062 | -85.1% |
| Skill sorting | — | 0.283 | 0.133 | -53.1% |

*Note:* This table summarizes the effects of the endogenous regulation mechanism on a set of variables of interest. The column "1980, benchmark" shows moments for the economy calibrated to 1980. The column "2007, benchmark" displays moments for the benchmark economy calibrated to 2007. The column "2007, counterfact" shows moments for the 2007 economy in which regulation is fixed at the 1980 level. The column "Contrib" calculates contribution of the rise of regulation to the value of a variable of interest. For output, mean wages, mean prices and skill sorting, the contribution is the comparison of the level in the benchmark 2007 economy with the level in the counterfactual 2007 economy. For variance of wages and house prices the contribution is the comparison of the rate of growth between the benchmark 2007 economy and the 1980 economy with the rate of growth between the counterfactual 2007 economy and the 1980 economy. See Section 1.6 for details.

Figure 1.15: City size: benchmark vs counterfactual




*Note:* The figure displays the relationship between the size of the labor force of each metropolitan area in the benchmark 2007 economy and the counterfactual 2007 economy in which regulation is at the level of 1980. See Section 1.6 for details.

Table 1.11: Effects of the rise in regulation from 1980 to 2007, by city

| | Regulation, $\zeta_m^{\text{reg}}$ | | Change, % | | | |
|---|---|---|---|---|---|---|
| | benchmark | counterfact | Popul | Wage | Prices | Output |
| New York, NY-NJ-CT-PA | 0.1332 | 0.0386 | 61 | -5.4 | -77 | 54 |
| Los Angeles, CA | 0.1211 | 0.0540 | 43 | -0.6 | -64 | 44 |
| Chicago, IL | 0.1170 | 0.0628 | 73 | -2.7 | -53 | 68 |
| Dallas, TX | 0.0796 | 0.0679 | 10 | -1.1 | -15 | 8 |
| Washington, DC-MD-VA | 0.0868 | 0.0472 | 14 | -2.7 | -44 | 11 |
| Philadelphia, PA-NJ | 0.0926 | 0.0623 | 14 | -1.5 | -35 | 12 |
| Houston, TX | 0.0853 | 0.0641 | 10 | -1.6 | -26 | 9 |
| Atlanta, GA | 0.0853 | 0.0456 | 21 | -2.2 | -43 | 19 |
| San Francisco, CA | 0.1244 | 0.0530 | 39 | -2.0 | -66 | 36 |
| Detroit, MI | 0.0944 | 0.0647 | 11 | -0.7 | -35 | 11 |
| Boston, MA-NH | 0.1011 | 0.0498 | 18 | -2.8 | -53 | 15 |
| Minneapolis-St Paul, MN | 0.0982 | 0.0481 | 19 | -1.4 | -51 | 18 |
| Phoenix, AZ | 0.0853 | 0.0490 | 8 | -0.6 | -41 | 7 |
| Riverside-San Bernardino, CA | 0.0759 | 0.0489 | 33 | 0.4 | -30 | 32 |
| St Louis, MO-IL | 0.0892 | 0.0636 | 8 | -0.7 | -30 | 7 |
| Seattle, WA | 0.1023 | 0.0529 | 16 | -1.5 | -51 | 15 |
| Denver, CO | 0.0861 | 0.0509 | 14 | -1.5 | -39 | 13 |
| Baltimore, MD | 0.1038 | 0.0504 | 10 | -1.1 | -53 | 9 |
| Tampa-St Petersburg, FL | 0.0834 | 0.0465 | 20 | -0.9 | -40 | 19 |
| San Diego, CA | 0.1338 | 0.0469 | 51 | -1.4 | -71 | 48 |
| Cleveland, OH | 0.0878 | 0.0634 | 12 | -0.7 | -29 | 11 |
| Pittsburgh, PA | 0.0826 | 0.0597 | 9 | -1.0 | -27 | 8 |
| Miami, FL | 0.0977 | 0.0329 | 80 | -1.9 | -60 | 76 |
| Orlando, FL | 0.0853 | 0.0481 | 17 | -0.9 | -40 | 16 |
| Kansas City, MO-KS | 0.0689 | 0.0470 | -6 | -0.1 | -28 | -6 |

*Note:* The table displays the effect of the endogenous regulation mechanism for the 25 largest metropolitan areas in the U.S. The columns "Regulation, benchmark" and "Regulation, counterfact" show the levels of regulation in the benchmark calibration and the imputed 1980 levels, respectively. The next four columns show how much population, mean wages, house prices and output would change if in 2007 regulation remained at the 1980 level. See Section 1.6 for details.

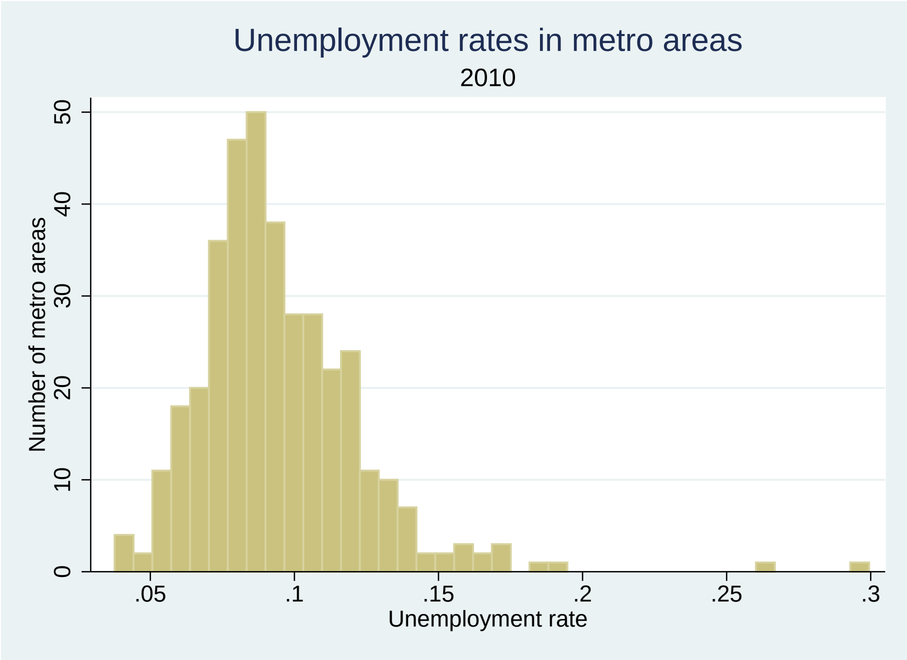
Table 1.12: Federal policy interventions

| | Benchmark | Cap on Reg | Tax on Reg |
|---|---|---|---|
| Mean regulation | 0.070 | 0.065 | 0.062 |
| S.d. regulation | 0.016 | 0.009 | 0.008 |
| Output | 1.000 | 1.014 | 1.015 |
| Mean wages | 1.000 | 1.014 | 1.014 |
| Dispersion of wages (var of log) | 0.0162 | 0.0157 | 0.0154 |
| Mean house prices | 1.000 | 0.813 | 0.748 |
| Dispersion of house prices (var of log) | 0.141 | 0.089 | 0.073 |
| Homeownership rate | 0.734 | 0.806 | 0.820 |
| Homeownership, high-skl/low-skl | 1.203 | 1.150 | 1.117 |

*Note:* This table summarizes the results of government intervention in the way cities choose regulation. The column "Benchmark" shows moments from the benchmark 2007 calibration. The column "Cap on Reg" displays moments from the 2007 economy in which in maximum level of regulation that a city can choose is capped. See Section 1.7.1 for details. The column "Tax on Reg" shows moments from the 2007 economy in which the central government introduces a progressive property tax. See Section 1.7.2 for details.

# Tables and Figures for Chapter 2

Figure 2.1: Distribution of Local Unemployment Rates

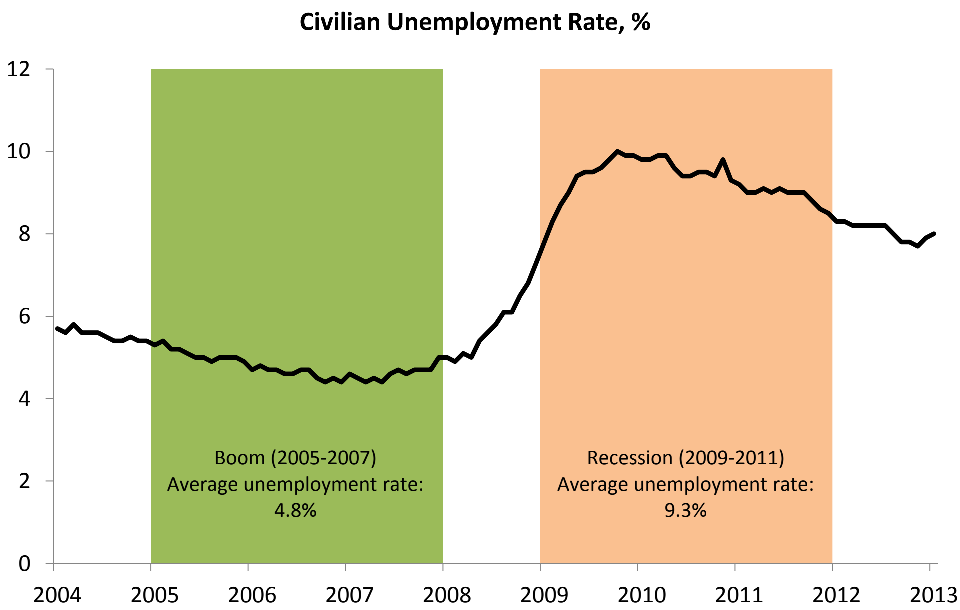



*Note:* this figure displays the number of metropolitan areas in the U.S. by average unemployment rate in 2010. Data source: U.S. Bureau of Labor Statistics, Local Area Unemployment Statistics, retrieved from http://www.bls.gov/lau/metrossa.htm.

Figure 2.2: Persistence of Local Unemployment Rates


*Note:* this figure displays the relationship between the average unemployment rate in a metropolitan area in 2003 and the unemployment rate one, two, four and ten years after (2004, 2005, 2007 and 2013). This relationship also holds for base years other than 2003. Data source: U.S. Bureau of Labor Statistics, Local Area Unemployment Statistics, retrieved from http://www.bls.gov/lau/metrossa.htm.

Figure 2.3: Unemployment Rate in the U.S., 2004-2013




*Note:* this figure displays unemployment rate in the U.S. for the two periods used in the calibration of the model: 2005-2007 and 2009-2011. See Sections 2.3 and 2.4 for details. Data source: U.S. Bureau of Labor Statistics, Civilian Unemployment Rate [UNRATE], retrieved from FRED, Federal Reserve Bank of St. Louis.

Table 2.1: Groups of metropolitan areas by unemployment and productivity

| Group | # MSAs | Workforce | Unempl. | Mean wage | Examples |
|---|---|---|---|---|---|
| LULW | 128 | 17.4 mln | 3.5% | $45,733 | Dallas, Phoenix, Pittsburgh |
| HULW | 98 | 11.3 mln | 5.2% | $44,396 | St Louis, Cleveland, Cincinnati |
| LUHW | 34 | 11.0 mln | 3.9% | $58,547 | San Francisco, Washington DC |
| HUHW | 23 | 14.5 mln | 5.2% | $54,311 | New York, Chicago, Detroit |

*Note:* all statistics in the table are calculated for the sample of labor force used in this paper. See Section 2.3.1 for details. Data source: American Community Survey 2005-2007, retrieved from IPUMS-USA.

Table 2.2: Parameters calibrated outside the model

| | | | **Source** |
|---|---|---|---|
| Discount factor (annualized) | $\beta$ | 0.96 | |
| Age-specific productivity | $\phi_0$ | 18131 | Age-income profiles |
| | $\phi_1$ | 155.17 | |
| | $\phi_2$ | -0.2488 | |
| Oldest fertile age | $T_f$ | 40 | Monte and Ellis (2014) |
| Job destruction rate | $\delta$ | 0.0118 | Gomes (2015) |
| Skill complementarity | $\eta$ | 0.60 | Card (2009) |
| Cross-location search friction | $\Delta_{ij}$ | 0.394 | Marinescu and Rathelot (2014) |
| Housing supply parameter | $\zeta$ | 1.38 | Blackley (1999) |
| Housing depreciation | $\rho$ | 0.994 | Malpezzi, Ozanne and Thibodeau (1987) |
| Interest rate (annualized) | $r$ | 0.04 | |
| Unemployment benefits | $\bar{\upsilon}$ | 0.5 | Empirical evidence |

*Note:* See Section 2.3 for details.

Table 2.3: Parameters calibrated within the model

| | | |
|---|---|---|
| Productivity of the high-skilled | $\psi_H$ | 1.740 |
| Exogenous TFP, LULW city | $A_{\text{LULW}}$ | 1.000 |
| Exogenous TFP, HULW city | $A_{\text{HULW}}$ | 0.973 |
| Exogenous TFP, LUHW city | $A_{\text{LUHW}}$ | 1.299 |
| Exogenous TFP, HUHW city | $A_{\text{HUHW}}$ | 1.206 |
| Job offer arrival rate, LULW city | $\theta_{\text{LULW}}$ | 0.3593 |
| Job offer arrival rate, HULW city | $\theta_{\text{HULW}}$ | 0.2371 |
| Job offer arrival rate, LUHW city | $\theta_{\text{LUHW}}$ | 0.3361 |
| Job offer arrival rate, HUHW city | $\theta_{\text{HUHW}}$ | 0.2484 |
| Standard deviation of utility shock | $\sigma_\varepsilon$ | 0.3491 |
| Disutility of living outside preferred location | $\mu$ | 0.2130 |
| Moving cost | $\kappa$ | 16.4073 |
| Moving cost, % of mean annual wage | | 15.6 |
| Moving cost, USD | | 8425 |
| Population with pref. for LULW city | $\xi_{\text{LULW}}$ | 0.33 |
| Population with pref. for HULW city | $\xi_{\text{HULW}}$ | 0.22 |
| Population with pref. for LUHW city | $\xi_{\text{LUHW}}$ | 0.19 |
| Population with pref. for HUHW city | $\xi_{\text{HUHW}}$ | 0.26 |
| Fraction born with pref. for own city | $\nu$ | 0.0779 |
| Housing supply elasticity parameter | $\zeta$ | 1.38 |
| Construction cost parameter | $\chi_{\text{LU-LW}}$ | 1.00 |
| Construction cost parameter | $\chi_{\text{HU-LW}}$ | 0.97 |
| Construction cost parameter | $\chi_{\text{LU-HW}}$ | 1.86 |
| Construction cost parameter | $\chi_{\text{HU-HW}}$ | 1.33 |
| Preference for housing | $\gamma$ | 0.109 |
| Minimum area requirement | $h_{\min}$ | 1.02 |
| Borrowing limit | $B$ | 4.40 |
| Borrowing limit, % mean monthly wage | | 50.2 |

*Note:* See Section 2.3 for details.

Table 2.4: Model performance, benchmark calibration (2005-2007)

| | Model | Data |
|---|---|---|
| Skill premium | 1.72 | 1.72 |
| Mean wage %, LULW city | 1.00 | 1.00 |
| Mean wage %, HULW city | 0.97 | 0.97 |
| Mean wage %, LUHW city | 1.27 | 1.28 |
| Mean wage %, HUHW city | 1.19 | 1.19 |
| Unemp rate %, LULW city | 3.56 | 3.54 |
| Unemp rate %, HULW city | 5.21 | 5.22 |
| Unemp rate %, LUHW city | 3.87 | 3.86 |
| Unemp rate %, HUHW city | 5.24 | 5.24 |
| Mobility rate, % of labor force per year | 1.99 | 1.99 |
| Mobility rate, high/low skilled | 1.44 | 1.43 |
| Mobility rate, ages 25-44 | 3.49 | 3.16 |
| Migration, (EU+UU)/(EE+UE) | 0.13 | 0.13 |
| Population, LULW city | 0.32 | 0.32 |
| Population, HULW city | 0.21 | 0.21 |
| Population, LUHW city | 0.20 | 0.20 |
| Population, HUHW city | 0.27 | 0.27 |
| Rent, LULW city | 1.00 | 1.00 |
| Rent, HULW city | 0.85 | 0.85 |
| Rent, LUHW city | 1.53 | 1.52 |
| Rent, HUHW city | 1.24 | 1.23 |
| Housing expenditure share | 0.24 | 0.24 |
| Expenditure share, high/low skilled | 0.74 | 0.74 |
| Population with negative net worth | 0.18 | 0.19 |

*Note:* See Section 2.3 for details.

Table 2.5: Model performance, 2009-2011 calibration

| | Model | Data |
|---|---|---|
| Skill premium | 1.72 | 1.74 |
| Mean wage %, LULW city | 1.00 | 1.00 |
| Mean wage %, HULW city | 0.97 | 0.96 |
| Mean wage %, LUHW city | 1.28 | 1.29 |
| Mean wage %, HUHW city | 1.19 | 1.18 |
| Unemp rate %, LULW city | 6.58 | 6.57 |
| Unemp rate %, HULW city | 8.14 | 8.13 |
| Unemp rate %, LUHW city | 6.85 | 6.86 |
| Unemp rate %, HUHW city | 8.79 | 8.78 |
| Mobility rate, % of labor force per year | 2.28 | 1.74 |
| Mobility rate, high/low skilled | 1.85 | 1.66 |
| Mobility rate, ages 25-44 | 3.62 | 2.91 |
| Migration, (EU+UU)/(EE+UE) | 0.12 | 0.24 |
| Population, LULW city | 0.31 | 0.30 |
| Population, HULW city | 0.21 | 0.20 |
| Population, LUHW city | 0.21 | 0.23 |
| Population, HUHW city | 0.27 | 0.27 |
| Rent, LULW city | 1.00 | 1.00 |
| Rent, HULW city | 0.85 | 0.86 |
| Rent, LUHW city | 1.54 | 1.53 |
| Rent, HUHW city | 1.24 | 1.24 |
| Housing expenditure share | 0.24 | 0.24 |
| Expenditure share, high/low skilled | 0.74 | 0.72 |
| Population with negative net worth | 0.10 | 0.26 |

*Note:* I recalibrate $\delta$ and $\theta_i$ to match unemployment rates in 2009-2011, and keep all other parameters as in the 2005-2007 calibration. See Section 2.4 for details.

Table 2.6: Effects of relocation subsidies in boom (2005-2007)

| Moving subsidy, frac moving cost | 0.00 | 0.10 | 0.20 | 0.30 | 0.40 | 0.50 | 0.60 | 0.70 |
|---|---|---|---|---|---|---|---|---|
| Unemployment rate, % | 4.42 | 4.40 | 4.38 | 4.36 | 4.33 | 4.28 | 4.23 | 4.18 |
| GDP | 1.000 | 1.001 | 1.001 | 1.002 | 1.003 | 1.004 | 1.006 | 1.008 |
| Gov't expenses | 0.179 | 0.179 | 0.178 | 0.178 | 0.179 | 0.180 | 0.183 | 0.191 |
| Gov't expenses, % GDP | 0.826 | 0.823 | 0.821 | 0.820 | 0.821 | 0.825 | 0.838 | 0.872 |
| Consumption of goods | 1.000 | 1.000 | 1.000 | 1.000 | 1.001 | 1.001 | 1.001 | 1.001 |
| Consumption of housing | 1.000 | 1.000 | 0.999 | 0.998 | 0.998 | 0.997 | 0.995 | 0.993 |
| Unemp rate LULW city, % | 3.56 | 3.56 | 3.55 | 3.53 | 3.52 | 3.50 | 3.47 | 3.43 |
| Unemp rate HULW city, % | 5.21 | 5.17 | 5.12 | 5.06 | 4.99 | 4.87 | 4.73 | 4.58 |
| Unemp rate LUHW city, % | 3.87 | 3.85 | 3.84 | 3.82 | 3.80 | 3.76 | 3.74 | 3.75 |
| Unemp rate HUHW city, % | 5.24 | 5.22 | 5.20 | 5.19 | 5.17 | 5.15 | 5.12 | 5.09 |
| Population LULW city | 0.316 | 0.316 | 0.316 | 0.315 | 0.314 | 0.313 | 0.311 | 0.309 |
| Population HULW city | 0.211 | 0.211 | 0.210 | 0.209 | 0.209 | 0.207 | 0.204 | 0.201 |
| Population LUHW city | 0.205 | 0.206 | 0.206 | 0.208 | 0.209 | 0.211 | 0.214 | 0.218 |
| Population HUHW city | 0.266 | 0.266 | 0.266 | 0.267 | 0.267 | 0.268 | 0.270 | 0.271 |
| Mean wage LULW city | 7.98 | 7.97 | 7.97 | 7.97 | 7.96 | 7.96 | 7.95 | 7.95 |
| Mean wage HULW city | 7.71 | 7.71 | 7.70 | 7.70 | 7.69 | 7.68 | 7.67 | 7.70 |
| Mean wage LUHW city | 10.14 | 10.15 | 10.16 | 10.18 | 10.20 | 10.23 | 10.26 | 10.26 |
| Mean wage HUHW city | 9.46 | 9.46 | 9.46 | 9.47 | 9.47 | 9.47 | 9.46 | 9.45 |
| Rent LULW city | 1.09 | 1.08 | 1.08 | 1.08 | 1.08 | 1.08 | 1.08 | 1.08 |
| Rent HULW city | 0.92 | 0.92 | 0.92 | 0.92 | 0.92 | 0.92 | 0.91 | 0.91 |
| Rent LUHW city | 1.66 | 1.66 | 1.66 | 1.67 | 1.67 | 1.68 | 1.68 | 1.69 |
| Rent HUHW city | 1.34 | 1.34 | 1.34 | 1.34 | 1.34 | 1.34 | 1.35 | 1.35 |
| Mobility rate, % | 1.99 | 2.08 | 2.18 | 2.34 | 2.57 | 2.90 | 3.40 | 4.16 |
| Mobility rate, high-skilled | 2.46 | 2.68 | 2.94 | 3.29 | 3.75 | 4.36 | 5.24 | 6.63 |
| Mobility rate, low-skilled | 1.71 | 1.72 | 1.73 | 1.77 | 1.87 | 2.04 | 2.31 | 2.69 |
| Migration, (EU+UU)/(EE+UE) | 0.13 | 0.13 | 0.14 | 0.16 | 0.19 | 0.22 | 0.30 | 0.45 |

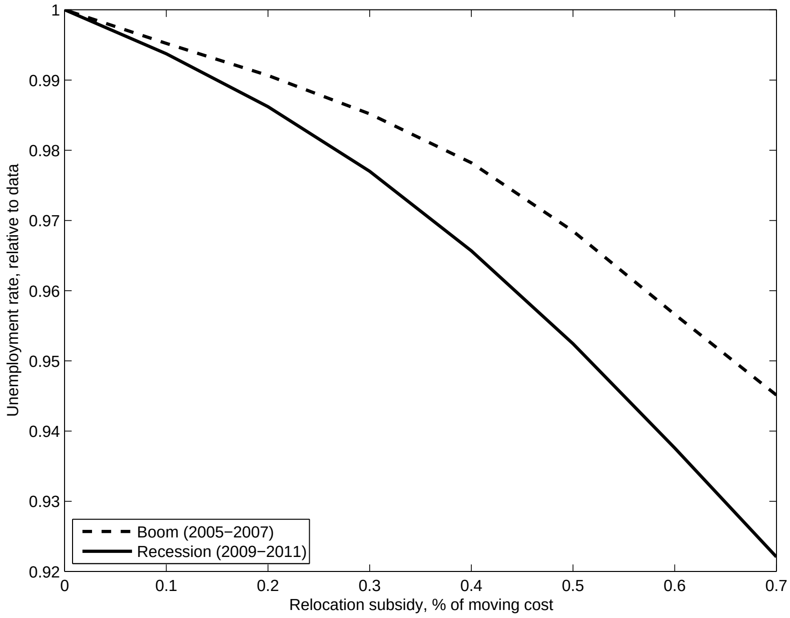
*Note:* The table shows the effects of various levels of relocation subsidies on the economy calibrated to 2005-2007. See Section 2.4.1 for details.

Table 2.7: Effects of relocation subsidies in recession (2009-2011)

| Moving subsidy, frac moving cost | 0.00 | 0.10 | 0.20 | 0.30 | 0.40 | 0.50 | 0.60 | 0.70 |
|---|---|---|---|---|---|---|---|---|
| Unemployment rate, % | 7.55 | 7.51 | 7.45 | 7.38 | 7.29 | 7.19 | 7.08 | 6.97 |
| GDP | 1.000 | 1.001 | 1.003 | 1.005 | 1.007 | 1.010 | 1.013 | 1.016 |
| Gov't expenses | 0.312 | 0.310 | 0.309 | 0.308 | 0.308 | 0.309 | 0.314 | 0.326 |
| Gov't expenses, % GDP | 1.483 | 1.475 | 1.467 | 1.459 | 1.455 | 1.458 | 1.474 | 1.525 |
| Consumption of goods | 1.000 | 1.000 | 1.001 | 1.002 | 1.003 | 1.004 | 1.005 | 1.005 |
| Consumption of housing | 1.000 | 0.999 | 0.998 | 0.997 | 0.996 | 0.994 | 0.992 | 0.989 |
| Unemp rate LULW city, % | 6.58 | 6.55 | 6.51 | 6.46 | 6.40 | 6.32 | 6.20 | 6.07 |
| Unemp rate HULW city, % | 8.14 | 8.06 | 7.96 | 7.84 | 7.70 | 7.52 | 7.31 | 7.10 |
| Unemp rate LUHW city, % | 6.85 | 6.80 | 6.74 | 6.66 | 6.56 | 6.46 | 6.40 | 6.34 |
| Unemp rate HUHW city, % | 8.79 | 8.75 | 8.71 | 8.66 | 8.61 | 8.53 | 8.45 | 8.35 |
| Population LULW city | 0.314 | 0.313 | 0.312 | 0.311 | 0.309 | 0.305 | 0.301 | 0.297 |
| Population HULW city | 0.210 | 0.209 | 0.208 | 0.207 | 0.204 | 0.202 | 0.198 | 0.194 |
| Population LUHW city | 0.208 | 0.210 | 0.211 | 0.213 | 0.216 | 0.220 | 0.225 | 0.231 |
| Population HUHW city | 0.266 | 0.267 | 0.267 | 0.268 | 0.269 | 0.272 | 0.274 | 0.277 |
| Mean wage LULW city | 7.97 | 7.97 | 7.96 | 7.96 | 7.94 | 7.94 | 7.94 | 7.94 |
| Mean wage HULW city | 7.70 | 7.69 | 7.68 | 7.67 | 7.66 | 7.66 | 7.68 | 7.69 |
| Mean wage LUHW city | 10.19 | 10.21 | 10.23 | 10.27 | 10.31 | 10.33 | 10.33 | 10.33 |
| Mean wage HUHW city | 9.49 | 9.49 | 9.50 | 9.50 | 9.50 | 9.49 | 9.49 | 9.47 |
| Rent LULW city | 1.08 | 1.08 | 1.08 | 1.07 | 1.07 | 1.07 | 1.06 | 1.06 |
| Rent HULW city | 0.92 | 0.92 | 0.91 | 0.91 | 0.91 | 0.90 | 0.90 | 0.89 |
| Rent LUHW city | 1.66 | 1.67 | 1.67 | 1.68 | 1.68 | 1.70 | 1.71 | 1.72 |
| Rent HUHW city | 1.33 | 1.34 | 1.34 | 1.34 | 1.34 | 1.34 | 1.35 | 1.35 |
| Mobility rate, % | 2.28 | 2.46 | 2.71 | 3.07 | 3.54 | 4.15 | 5.01 | 6.40 |
| Mobility rate, high-skilled | 3.20 | 3.64 | 4.18 | 4.84 | 5.64 | 6.67 | 8.13 | 10.53 |
| Mobility rate, low-skilled | 1.73 | 1.76 | 1.84 | 2.01 | 2.29 | 2.66 | 3.16 | 3.95 |
| Migration, (EU+UU)/(EE+UE) | 0.12 | 0.13 | 0.14 | 0.17 | 0.20 | 0.24 | 0.32 | 0.48 |

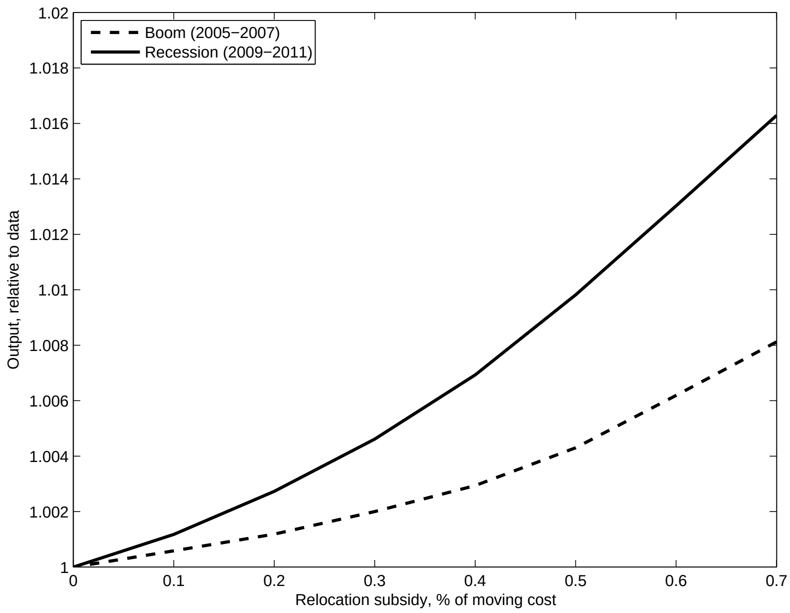
*Note:* The table shows the effects of various levels of relocation subsidies on the economy calibrated to 2009-2011. See Section 2.4.1 for details.

Figure 2.4: Effect of moving subsidies on national unemployment



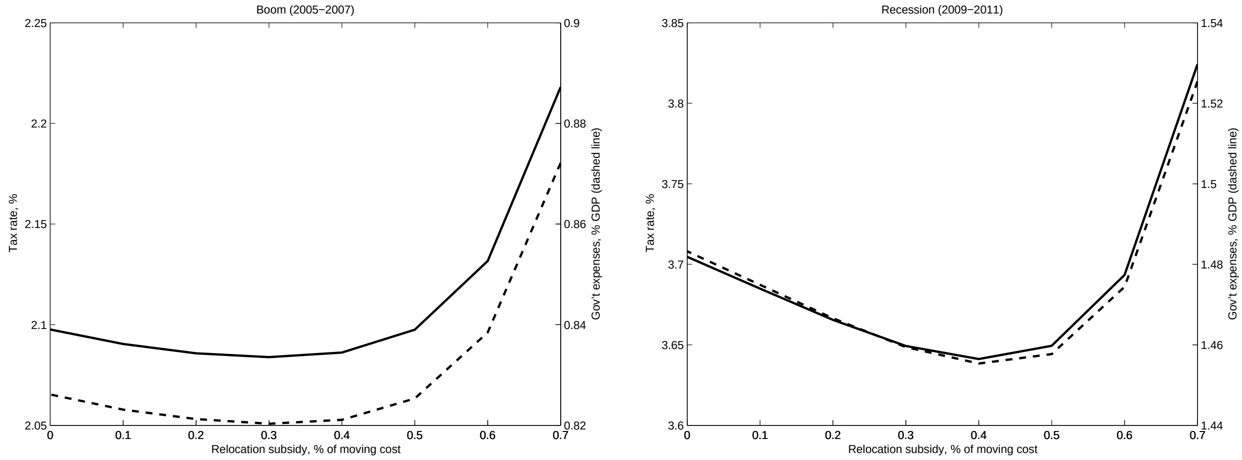

*Note:* The figure shows the effect of various levels of relocation subsidies on the national level of unemployment in the economies calibrated to 2005-2007 and 2009-2011. See Section 2.4.1 for details.

Figure 2.5: Effect of moving subsidies on productivity




*Note:* The figure shows the effect of various levels of relocation subsidies on the national level of output in the economies calibrated to 2005-2007 and 2009-2011. See Section 2.4.1 for details.

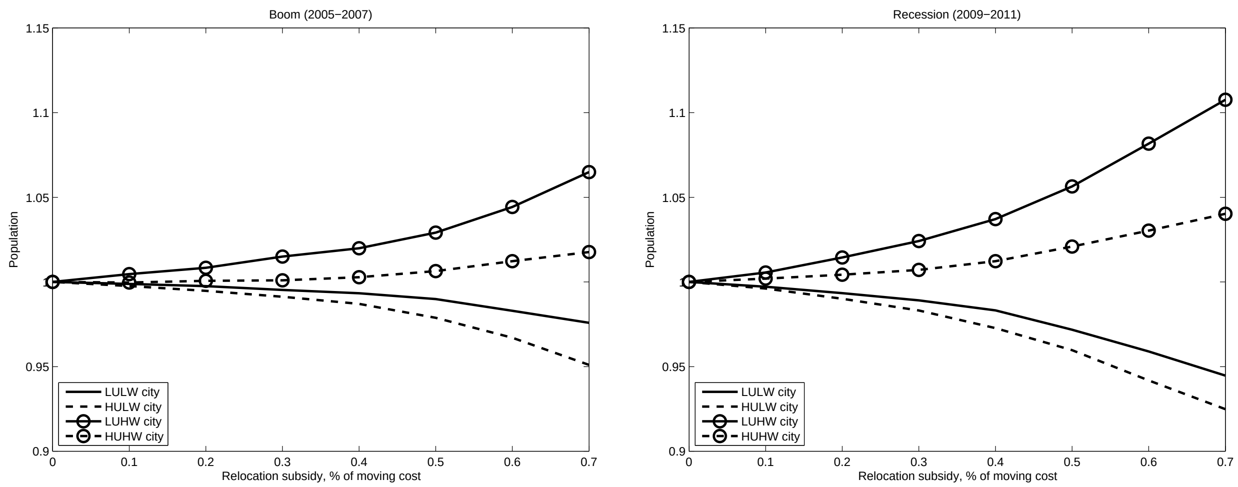
Figure 2.6: Effect of moving subsidies on tax rate and government expenses




Panel (a) Panel (b)

*Note:* The figure shows the effect of various levels of relocation subsidies on the budget-balancing tax rate and government expenditures-to-GDP ratio in the economies calibrated to 2005-2007 (Panel a) and 2009-2011 (Panel b). See Section 2.4.1 for details.

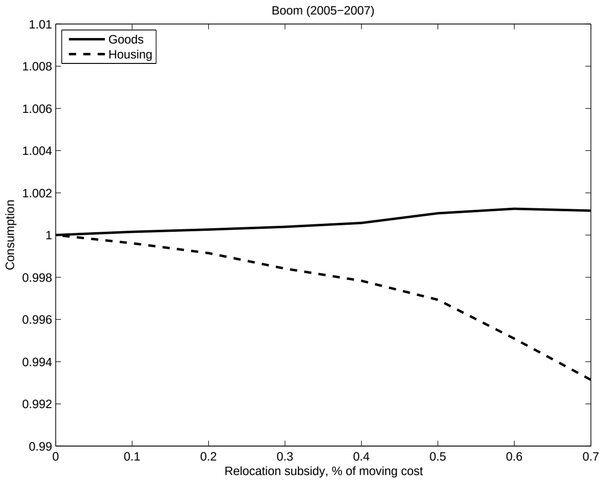
Figure 2.7: Effect of moving subsidies on distribution of labor across city groups



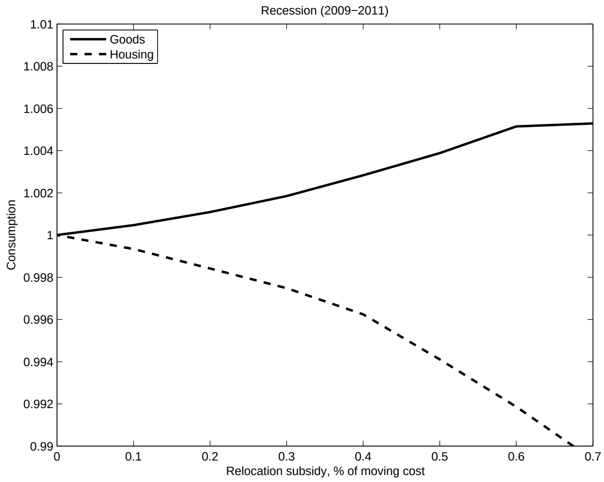

Panel (a) Panel (b)

*Note:* The figure shows the effect of various levels of relocation subsidies on the distribution of labor force across city groups in the economies calibrated to 2005-2007 (Panel a) and 2009-2011 (Panel b). See Section 2.4.1 for details.

Figure 2.8: Effect of moving subsidies on consumption




Panel (a)




Panel (b)

*Note:* The figure shows the effect of various levels of relocation subsidies on the consumption of goods and housing in the economies calibrated to 2005-2007 (Panel a) and 2009-2011 (Panel b). See Section 2.4.1 for details.

Table 2.8: Effects of moving subsidies in recession. Alternative policy: subsidize only inhabitants of high-unemployment cities

| Moving subsidy, frac moving cost | 0.00 | 0.10 | 0.20 | 0.30 | 0.40 | 0.50 | 0.60 | 0.70 |
|---|---|---|---|---|---|---|---|---|
| Unemployment rate, % | 7.55 | 7.53 | 7.50 | 7.46 | 7.41 | 7.36 | 7.30 | 7.23 |
| GDP | 1.000 | 1.001 | 1.001 | 1.002 | 1.003 | 1.005 | 1.006 | 1.007 |
| Gov't expenses | 0.312 | 0.311 | 0.310 | 0.310 | 0.309 | 0.310 | 0.310 | 0.313 |
| Gov't expenses, % GDP | 1.483 | 1.479 | 1.474 | 1.470 | 1.466 | 1.465 | 1.468 | 1.479 |
| Consumption of goods | 1.000 | 1.001 | 1.001 | 1.003 | 1.004 | 1.005 | 1.007 | 1.010 |
| Consumption of housing | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.001 | 1.001 | 1.003 |
| Unemp rate LULW city, % | 6.58 | 6.59 | 6.61 | 6.62 | 6.64 | 6.66 | 6.69 | 6.72 |
| Unemp rate HULW city, % | 8.14 | 8.06 | 7.95 | 7.81 | 7.66 | 7.46 | 7.22 | 6.93 |
| Unemp rate LUHW city, % | 6.85 | 6.84 | 6.84 | 6.82 | 6.81 | 6.81 | 6.81 | 6.84 |
| Unemp rate HUHW city, % | 8.79 | 8.75 | 8.71 | 8.67 | 8.61 | 8.54 | 8.44 | 8.34 |
| Population LULW city | 0.314 | 0.314 | 0.314 | 0.314 | 0.314 | 0.314 | 0.314 | 0.316 |
| Population HULW city | 0.210 | 0.209 | 0.208 | 0.207 | 0.205 | 0.202 | 0.199 | 0.195 |
| Population LUHW city | 0.208 | 0.209 | 0.210 | 0.210 | 0.211 | 0.212 | 0.214 | 0.215 |
| Population HUHW city | 0.266 | 0.266 | 0.267 | 0.267 | 0.268 | 0.270 | 0.271 | 0.273 |
| Mean wage LULW city | 7.97 | 7.97 | 7.98 | 7.97 | 7.97 | 7.98 | 7.97 | 7.96 |
| Mean wage HULW city | 7.70 | 7.69 | 7.69 | 7.68 | 7.67 | 7.68 | 7.69 | 7.72 |
| Mean wage LUHW city | 10.19 | 10.20 | 10.20 | 10.22 | 10.23 | 10.24 | 10.25 | 10.24 |
| Mean wage HUHW city | 9.49 | 9.49 | 9.49 | 9.49 | 9.49 | 9.48 | 9.48 | 9.47 |
| Rent LULW city | 1.08 | 1.08 | 1.08 | 1.08 | 1.08 | 1.08 | 1.08 | 1.08 |
| Rent HULW city | 0.92 | 0.92 | 0.91 | 0.91 | 0.91 | 0.91 | 0.90 | 0.90 |
| Rent LUHW city | 1.66 | 1.66 | 1.67 | 1.67 | 1.67 | 1.67 | 1.68 | 1.68 |
| Rent HUHW city | 1.33 | 1.33 | 1.34 | 1.34 | 1.34 | 1.34 | 1.34 | 1.34 |
| Mobility rate, % | 2.28 | 2.37 | 2.49 | 2.65 | 2.85 | 3.09 | 3.42 | 3.85 |
| Mobility rate, high-skilled | 3.20 | 3.42 | 3.67 | 3.96 | 4.30 | 4.69 | 5.19 | 5.91 |
| Mobility rate, low-skilled | 1.73 | 1.75 | 1.79 | 1.87 | 1.99 | 2.15 | 2.36 | 2.63 |
| Migration, (EU+UU)/(EE+UE) | 0.12 | 0.12 | 0.13 | 0.14 | 0.15 | 0.17 | 0.20 | 0.27 |

*Note:* The table shows the effects of various levels of relocation subsidies on the economy calibrated to 2009-2011, when only inhabitants of cities belonging to high-unemployment groups (HULW and HUHW) are eligible for the subsidies. See Section 2.4.2 for details.

Table 2.9: Effects of moving subsidies in recession. Alternative policy: subsidize only low-skilled workers

| Moving subsidy, frac moving cost | 0.00 | 0.10 | 0.20 | 0.30 | 0.40 | 0.50 | 0.60 | 0.70 |
|---:|---|---|---|---|---|---|---|---|
| Unemployment rate, % | 7.55 | 7.54 | 7.53 | 7.51 | 7.47 | 7.43 | 7.37 | 7.31 |
| GDP | 1.000 | 1.000 | 1.000 | 1.001 | 1.002 | 1.003 | 1.005 | 1.007 |
| Gov't expenses | 0.312 | 0.311 | 0.311 | 0.310 | 0.309 | 0.307 | 0.305 | 0.303 |
| Gov't expenses, % GDP | 1.483 | 1.481 | 1.478 | 1.473 | 1.466 | 1.456 | 1.444 | 1.431 |
| Consumption of goods | 1.000 | 1.000 | 1.000 | 1.001 | 1.001 | 1.002 | 1.003 | 1.005 |
| Consumption of housing | 1.000 | 1.000 | 1.000 | 1.000 | 0.999 | 0.998 | 0.997 | 0.995 |
| Unemp rate LULW city, % | 6.58 | 6.58 | 6.59 | 6.59 | 6.58 | 6.55 | 6.51 | 6.46 |
| Unemp rate HULW city, % | 8.14 | 8.13 | 8.11 | 8.06 | 8.00 | 7.92 | 7.82 | 7.67 |
| Unemp rate LUHW city, % | 6.85 | 6.83 | 6.80 | 6.76 | 6.70 | 6.64 | 6.56 | 6.50 |
| Unemp rate HUHW city, % | 8.79 | 8.77 | 8.75 | 8.74 | 8.72 | 8.70 | 8.67 | 8.66 |
| Population LULW city | 0.314 | 0.314 | 0.314 | 0.314 | 0.314 | 0.312 | 0.309 | 0.307 |
| Population HULW city | 0.210 | 0.210 | 0.210 | 0.209 | 0.208 | 0.206 | 0.204 | 0.201 |
| Population LUHW city | 0.208 | 0.208 | 0.209 | 0.209 | 0.210 | 0.212 | 0.216 | 0.219 |
| Population HUHW city | 0.266 | 0.266 | 0.266 | 0.267 | 0.267 | 0.268 | 0.270 | 0.272 |
| Mean wage LULW city | 7.97 | 7.97 | 7.97 | 7.97 | 7.96 | 7.96 | 7.97 | 7.97 |
| Mean wage HULW city | 7.70 | 7.70 | 7.69 | 7.68 | 7.68 | 7.68 | 7.68 | 7.71 |
| Mean wage LUHW city | 10.19 | 10.19 | 10.21 | 10.23 | 10.25 | 10.26 | 10.27 | 10.27 |
| Mean wage HUHW city | 9.49 | 9.49 | 9.49 | 9.49 | 9.48 | 9.47 | 9.46 | 9.44 |
| Rent LULW city | 1.08 | 1.08 | 1.08 | 1.08 | 1.08 | 1.08 | 1.07 | 1.07 |
| Rent HULW city | 0.92 | 0.92 | 0.92 | 0.92 | 0.91 | 0.91 | 0.91 | 0.90 |
| Rent LUHW city | 1.66 | 1.66 | 1.66 | 1.66 | 1.67 | 1.67 | 1.68 | 1.69 |
| Rent HUHW city | 1.33 | 1.33 | 1.33 | 1.34 | 1.34 | 1.34 | 1.34 | 1.34 |
| Mobility rate, % | 2.28 | 2.30 | 2.35 | 2.45 | 2.61 | 2.83 | 3.14 | 3.63 |
| Mobility rate, high-skilled | 3.20 | 3.21 | 3.24 | 3.28 | 3.34 | 3.42 | 3.52 | 3.62 |
| Mobility rate, low-skilled | 1.73 | 1.75 | 1.82 | 1.95 | 2.17 | 2.47 | 2.91 | 3.63 |
| Migration, (EU+UU)/(EE+UE) | 0.12 | 0.13 | 0.15 | 0.17 | 0.20 | 0.21 | 0.24 | 0.29 |

*Note:* The table shows the effects of various levels of relocation subsidies on the economy calibrated to 2009-2011, when only low-skilled workers are eligible for the subsidies. See Section 2.4.2 for details.

# Tables and Figures for Chapter 3

Table 3.1: Parameter Values (annualized)

| Parameter | Values |
|---|---|
| Population Growth Rate ($g_N$) | 0.011 |
| Productivity Growth Rate ($g$) | 0.026 |
| Depreciation Rate ($\delta$) | 0.040 |
| Skill accumulation technology ($\delta_z$) | 0.048 |
| Importance of Capital ($\alpha$) | 0.423 |
| Returns to Scale ($\gamma$) | 0.77 |
| Mean Log-managerial Ability ($\mu_z$) | 0 |
| Dispersion in Log-managerial Ability ($\sigma_z$) | 2.800 |
| Discount Factor ($\beta$) | 0.944 |
| Skill accumulation technology ($\theta$) | 0.881 |
| Skill accumulation technology ($\delta_\theta$) | 0.053 |
| Skill accumulation technology ($\theta_1$) | 0.68 |
| Skill accumulation technology ($\theta_2$) | 0.49 |

Note: Entries show model parameters calibrated for the benchmark economy. See text for details.

Table 3.2: Empirical Targets: Model and Data

| Statistic | Data | Model |
|---|---|---|
| Mean Size | 17.9 | 17.7 |
| Capital Output Ratio | 2.32 | 2.32 |
| Relative Earnings Growth ($\hat{g}$) (40-44/25-29) | 0.168 | 0.168 |
| Relative Earnings Growth ($\hat{g}$) (60-64/25-29) | 0.221 | 0.212 |
| Capital Share | 0.326 | 0.326 |
| *Fraction of Establishments* | | |
| 1-9 workers | 0.725 | 0.726 |
| 10-20 workers | 0.126 | 0.128 |
| 20-50 workers | 0.091 | 0.085 |
| 50-100 workers | 0.032 | 0.031 |
| 100+ workers | 0.026 | 0.030 |
| *Employment Share* | | |
| 1-9 workers | 0.151 | 0.172 |
| 10-20 workers | 0.094 | 0.100 |
| 20-50 workers | 0.164 | 0.148 |
| 50-100 workers | 0.128 | 0.121 |
| 100+ workers | 0.462 | 0.459 |

Note: Entries show the empirical targets used in the quantitative analysis and the model's performance. The fraction of establishments with 1-9 and 100+ workers, and the employment share with 100+ workers are explicit targets. See text for details.

Table 3.3: Effects of Economy-Wide Productivity

| Economy-Wide Productivity | $\overline{A}$= 1 | $\overline{A}$= 0.9 | $\overline{A}$= 0.8 | $\overline{A}$= 0.7 |
|---|---|---|---|---|
| <u>Statistic</u> | | | | |
| Output | 100 | 84.5 | 70.2 | 56.9 |
| Mean Size | 17.7 | 17.2 | 17.0 | 16.0 |
| Investment in Skills | 100 | 73.3 | 52.1 | 35.3 |
| Investment in Skills (% Output) | 0.92 | 0.80 | 0.68 | 0.57 |
| Number of Managers | 100 | 102.9 | 102.9 | 105.8 |
| Managerial Quality | 100 | 93.6 | 90.1 | 84.6 |
| Employment Share (100+) | 0.46 | 0.45 | 0.44 | 0.43 |
| Relative Earnings Growth ($\hat{g}$) | 0.22 | 0.16 | 0.10 | 0.04 |

<u>Note:</u> Entries show the effects on displayed variables associated to exogenous reductions in the level of economy-wide productivity ($\bar{A}$) across steady states. Column 2 report benchmark values ($\bar{A} = 1$). Column 3-5 report the changes emerging from reducing $\bar{A}$ below the benchmark value. See text for details.

Table 3.4: Effects of Size-Dependent Distortions

| Size Dependency ($\tau$) | 0 | 0.02 | 0.04 | 0.06 | 0.08 |
|---|---|---|---|---|---|
| Tax Wedge $\left(\frac{1-T(5\overline{y})}{1-T(y)}\right)$ | 1 | 0.97 | 0.94 | 0.91 | 0.88 |
| <u>Statistic</u> | | | | | |
| Output | 100.0 | 92.9 | 86.7 | 81.3 | 76.2 |
| Mean Size | 17.7 | 13.2 | 10.2 | 8.2 | 6.8 |
| Investment in Skills | 100.0 | 62.1 | 41.6 | 29.6 | 22.1 |
| Investment in Skills (% Output) | 0.92 | 0.61 | 0.44 | 0.33 | 0.27 |
| Number of Managers | 100.0 | 131.9 | 166.9 | 203.4 | 239.8 |
| Managerial Quality | 100.0 | 73.2 | 56.6 | 45.6 | 38.2 |
| Employment Share (100+) | 0.46 | 0.34 | 0.25 | 0.17 | 0.11 |
| Relative Earnings Growth ($\hat{g}$) | 0.22 | 0.09 | 0.02 | -0.02 | -0.05 |

<u>Note:</u> Entries show the effects on displayed variables associated to size-dependent distortions across steady states. Column 2 report benchmark values. Column 3-6 report the changes emerging from increasing the size dependency of distortions. See text for details.

Table 3.5: The Role of Managerial Skill Formation (%)

| Statistic | Fixed Lifetime Skills | | Fixed Initial Skills | |
|---|---|---|---|---|
| | $\tau = 0.02$ | $\bar{A} = 0.9$ | $\tau = 0.02$ | $\bar{A} = 0.9$ |
| Output | 23.8 | 7.6 | 27.0 | 6.6 |
| Mean Size | 8.6 | 100.0 | 18.6 | 100.0 |
| Managerial Quality | 24.7 | 100.0 | 34.8 | 100.0 |
| Employment Share 100+ | 23.6 | 100.0 | 14.8 | 100.0 |

Note: Entries show the percentage contribution of managerial skill formation for selected variables in response to the introduction of distortions of $\tau = 0.02$, and a reduction in economy-wide productivity to $\bar{A} = 0.9$. The case of 'Fixed Lifetime Skills' assumes that the age-profile of manager's skills does is unchanged relative to the benchmark economy. The case of 'Fixed Initial Skills' assumes that manager's skills at any age are given by the endowments at birth. See text for details.

Table 3.6: Effects of Initial Skill Distribution

| | Benchmark | 20% Lower Mean | 20% Higher CV |
|---|---|---|---|
| | $\mu_z = 0$ | $\mu_z = -0.223$ | $\mu_z = -0.1827$ |
| | $\sigma_z = 2.8$ | $\sigma_z = 2.8$ | $\sigma_z = 2.864$ |
| Statistic | | | |
| Output | 100 | 93.2 | 100 |
| Mean Size | 17.7 | 18.3 | 18.9 |
| Investment in Skills | 100 | 99.5 | 100.3 |
| Investment in Skills (% Output) | 0.92 | 0.98 | 0.95 |
| Number of Managers | 100 | 97.2 | 94.6 |
| Managerial Quality | 100 | 83.8 | 105.6 |
| Employment Share (100+) | 0.46 | 0.47 | 0.48 |
| Relative Earnings Growth ($\hat{g}$) | 0.22 | 0.26 | 0.24 |

Note: Entries show the percentage contribution of managerial skill formation for selected variables when the mean of the distribution of initial ability is 20% lower, and when dispersion (coefficient of variation) in initial ability is 20% higher (keeping mean ability constant). All other parameters are kept at their benchmark values. See text for details.

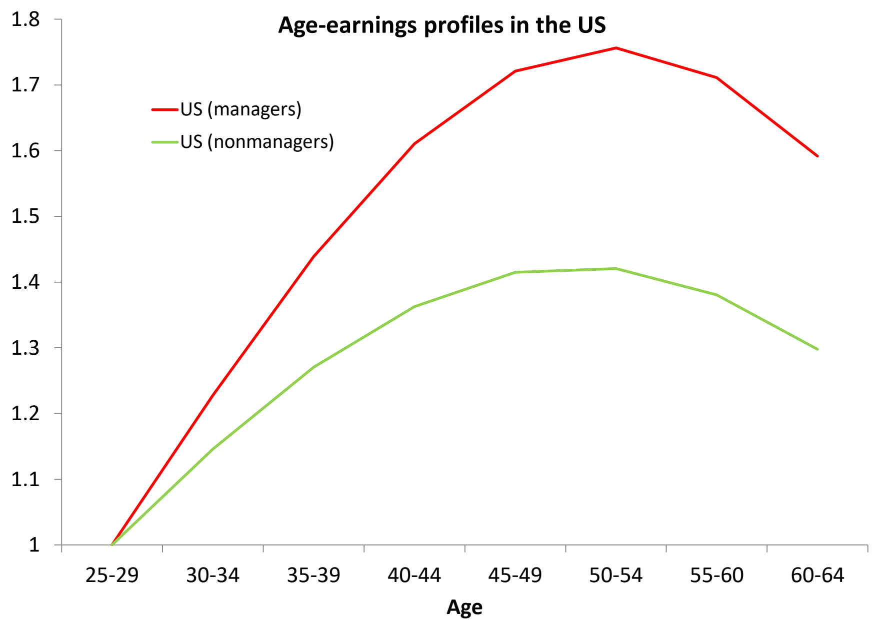



Figure 3.1

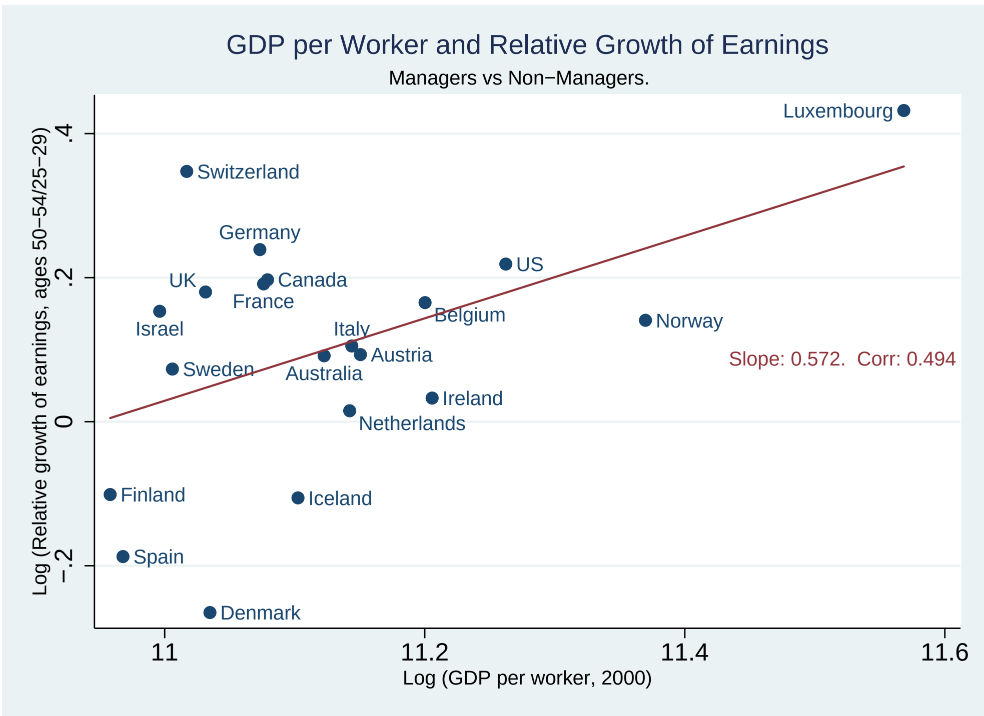



Figure 3.2

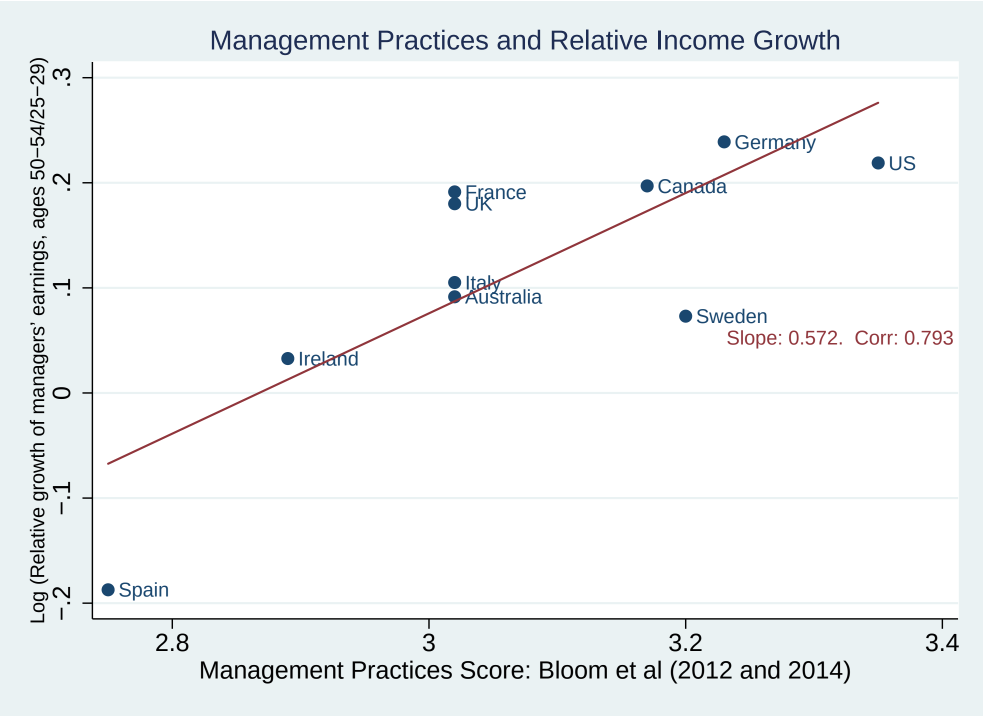



Figure 3.3

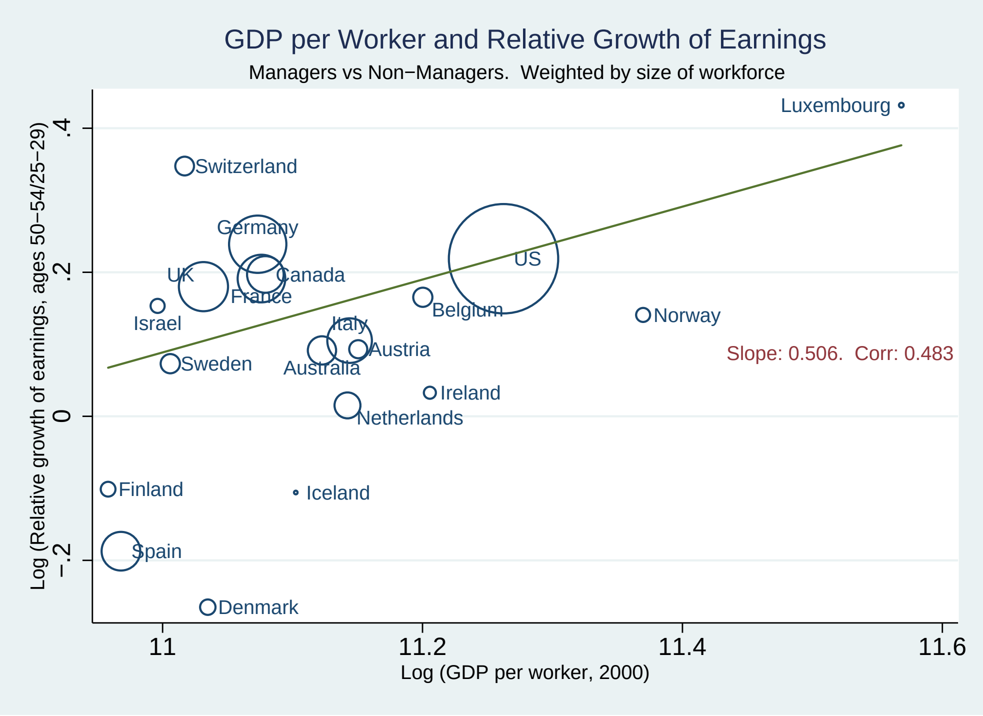



Figure 3.4

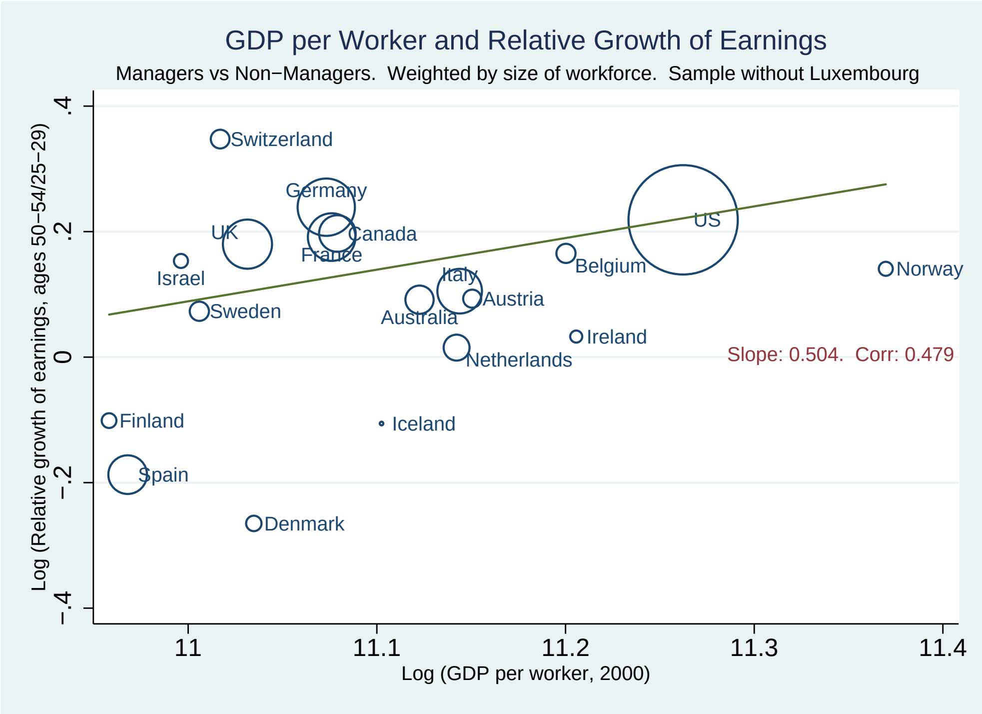



Figure 3.5


Figure 3.6

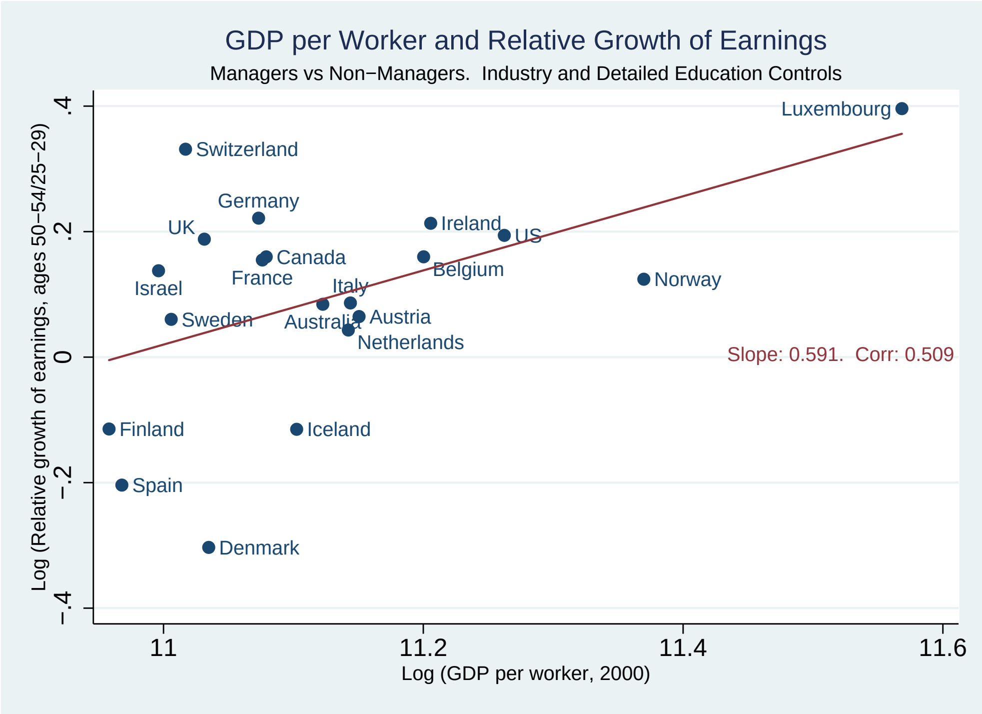



Figure 3.7

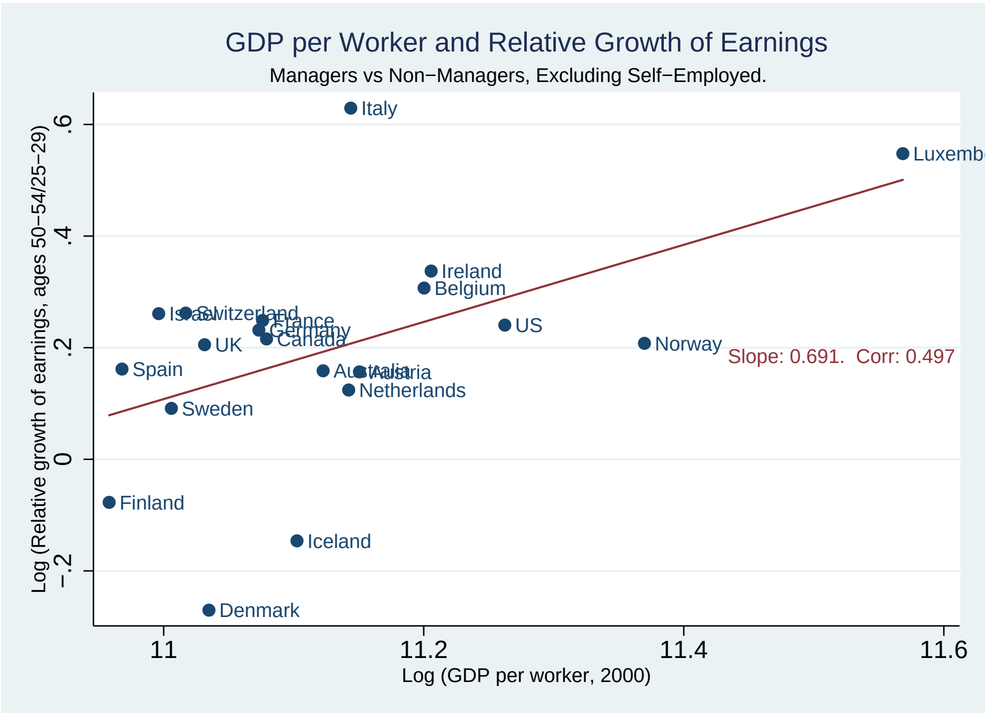



Figure 3.8

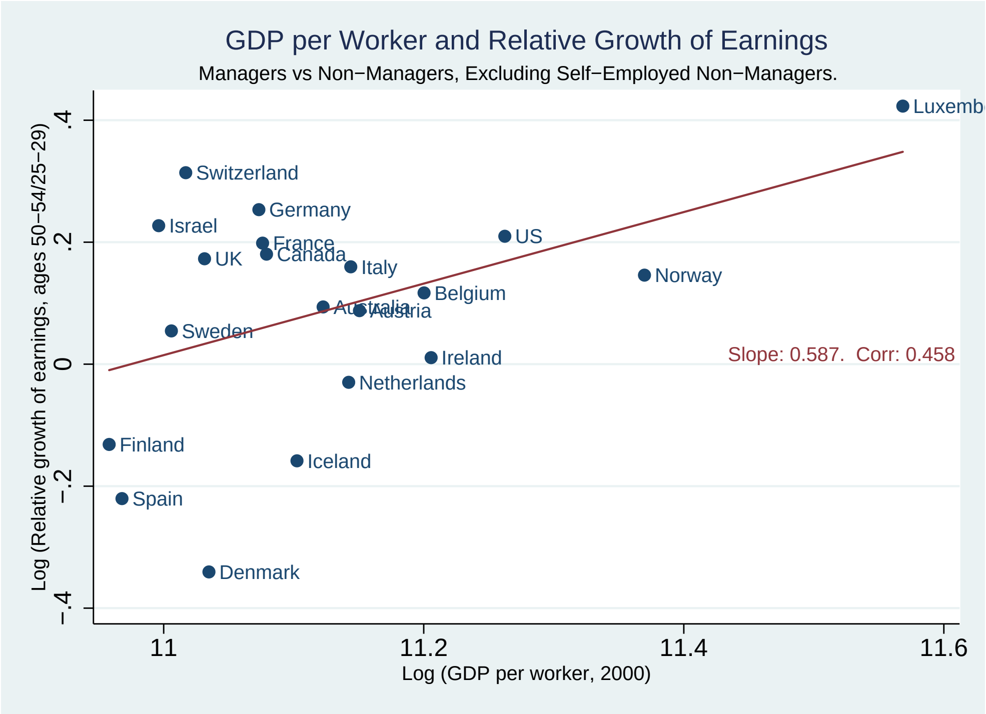



Figure 3.9

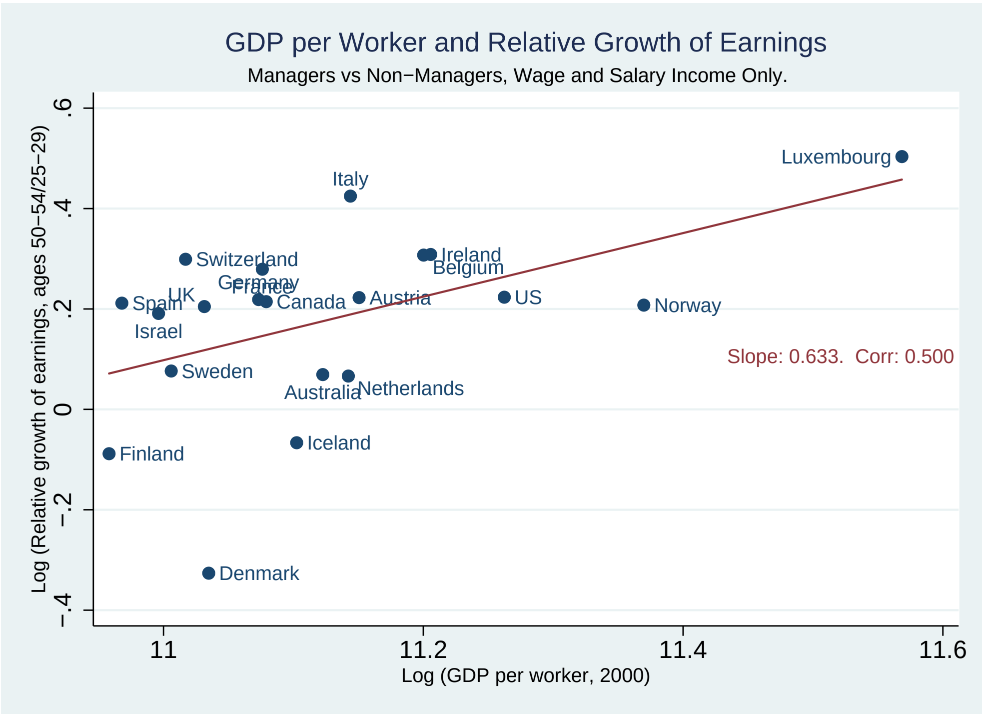



Figure 3.10

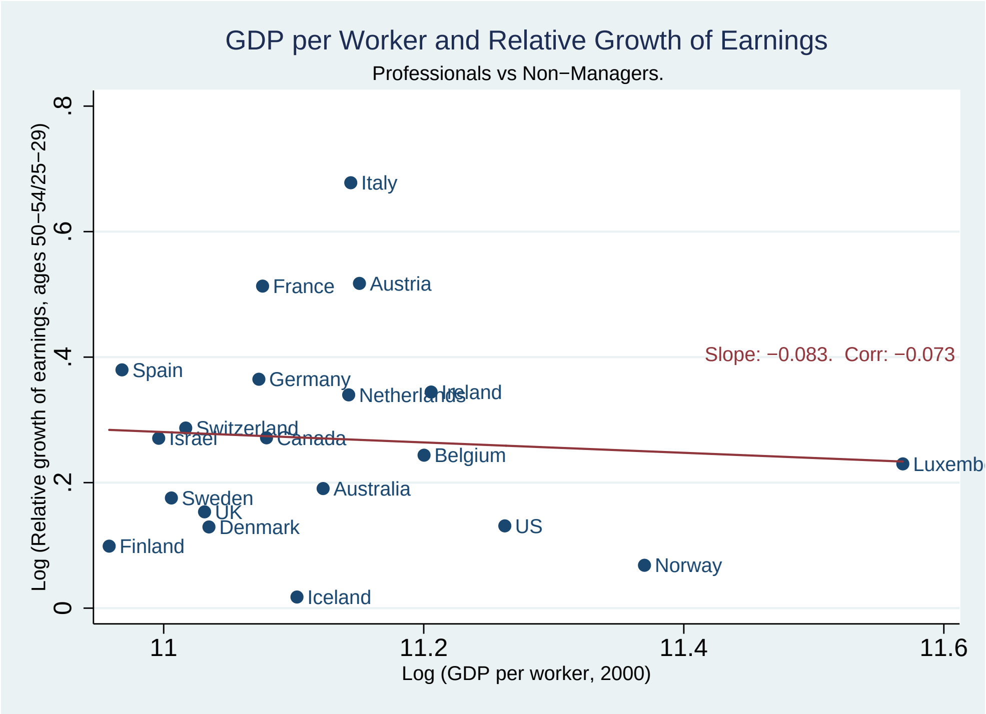



Figure 3.11

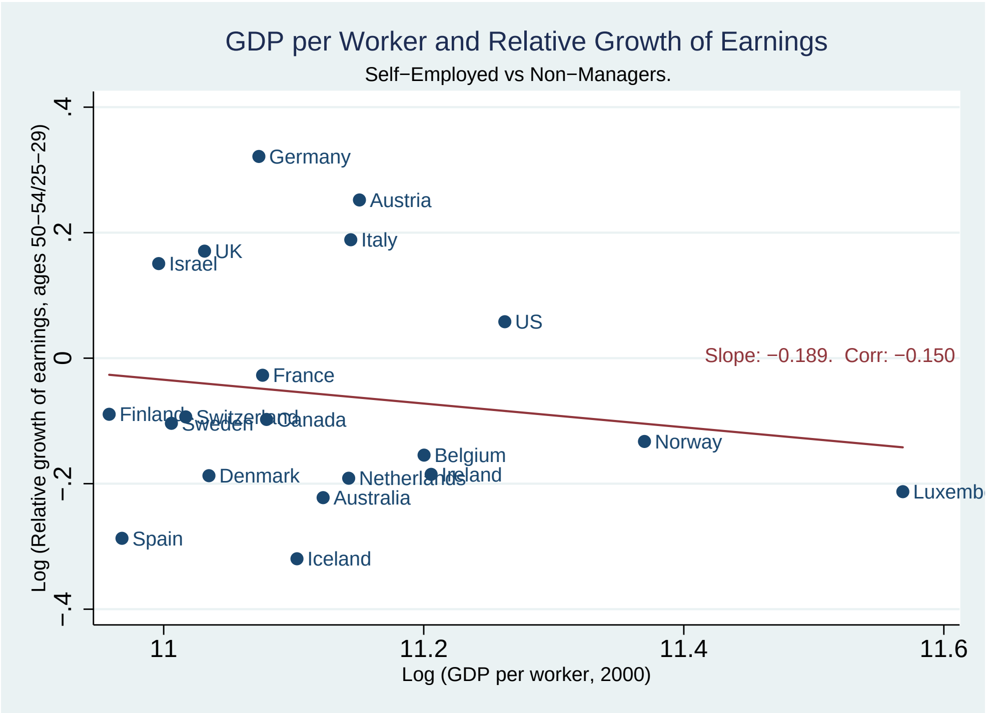



Figure 3.12

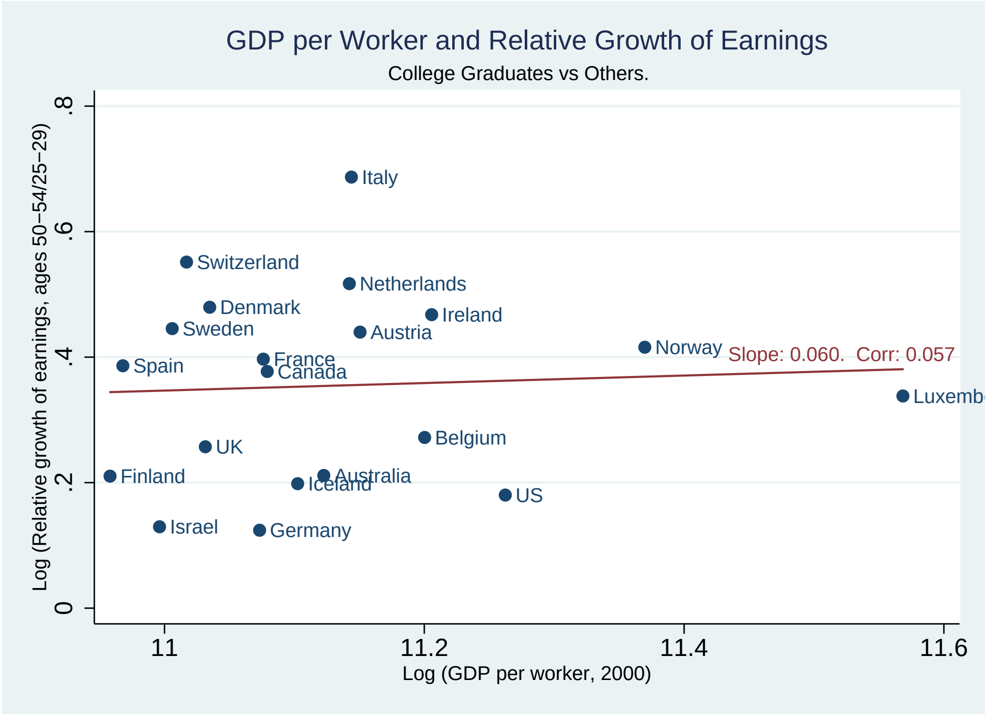



Figure 3.13

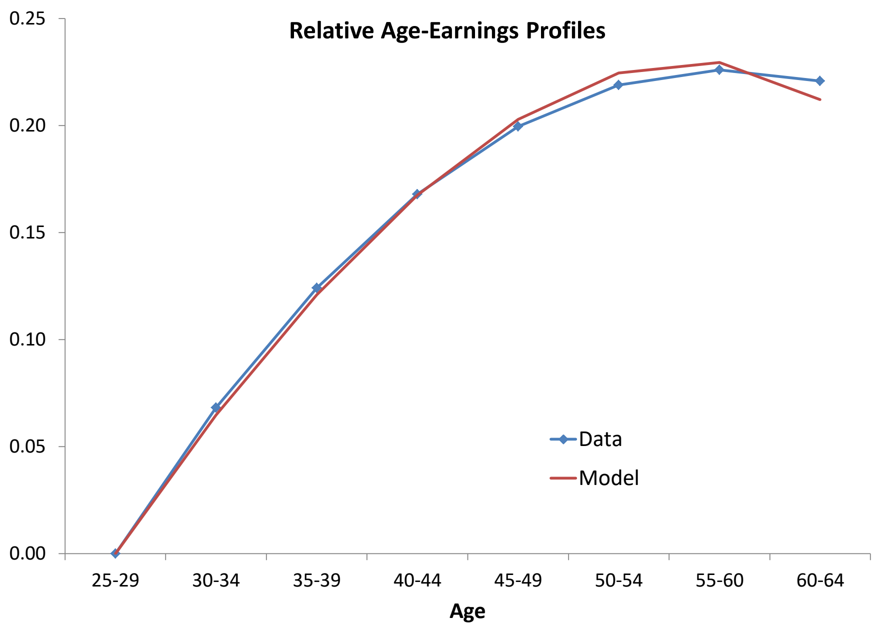



Figure 3.14

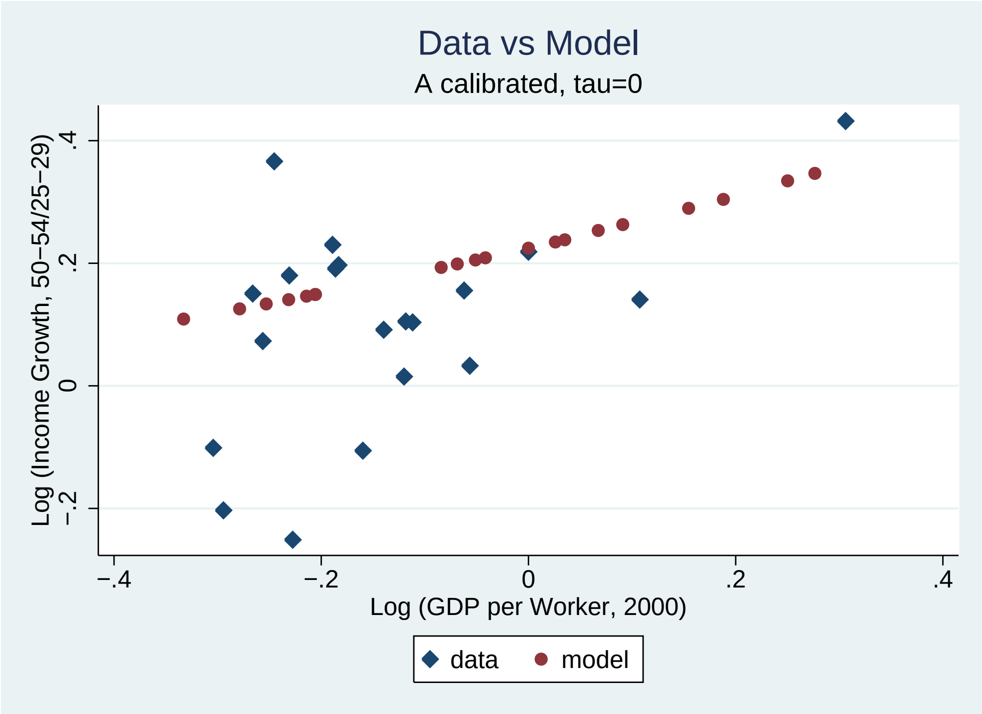



Figure 3.15

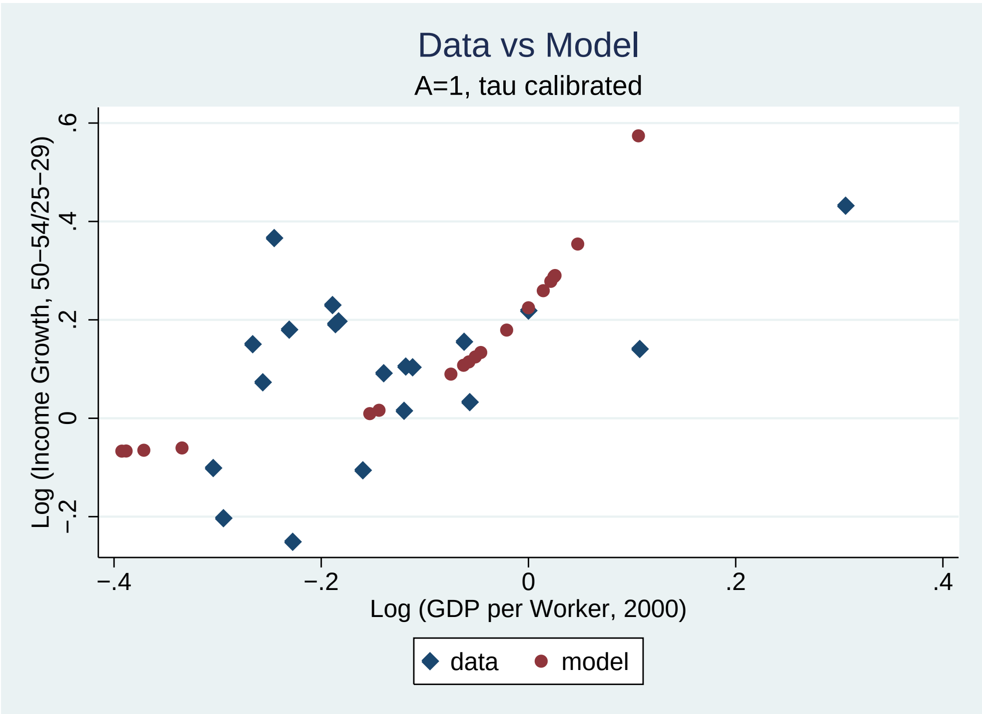



Figure 3.16

# Appendix A

# Chapter 1

## A.1 Solving the Model

Solving the model involves finding equilibrium objects (defined in Section 1.3.4) such that the equilibrium conditions hold for given parameters of the model. The sufficient condition for stationarity is that over time the measure of low and high skilled workers remains constant in every location. If it is the case, then wages are stationary, since they are fully determined by labor supply and exogenous productivity. The demand for housing is stationary as well, since everyone consumes one unit of housing. Then, for a given level of regulation, house prices and rents are stationary. Finally, the stationarity of prices and population implies that the incentives to regulate are unchanged from period to period, and therefore regulation is stationary as well.
**Solution algorithm.** The solution algorithm is described below.

1. Take the supply of each skill and the levels of regulation in every location from the data, and use them as an initial guess. Compute wages, house prices and rents.

2. Solve Bellman equations (1.3.5) and (1.3.6), and obtain decision rules for assets and ownership status. The Bellman equations are solved by backward induction, starting from the last period in which value functions are equal to the utility of the last period's consumption.

3. Compute the distribution of workers of each skill across locations using the value functions and the conditional choice probabilities (equation 1.3.9).

4. Use the value functions and the distribution of workers to compute regulation by maximizing the weighted social welfare function (equation 1.3.7) in every location. The social welfare function is maximized using the Nelder-Mead search algorithm.

5. Update wages using the new distribution of labor. Update house prices and rents using the new distribution of labor and the updated regulation levels.

6. Go back to step 2 and repeat steps 2 to 5 until the supply of each skill in every city converges.

All steps, except step 4, are trivial since they consist of plugging in solutions from previous steps into appropriate equations. However, finding the level of regulation that maximizes the social welfare (step 4) requires knowing value functions outside the stationary equilibrium, since changing the level of regulation may induce existing workers to change their

decisions on assets and homeownership status and the newborn workers to change their location choice.
This feature makes computation of regulation very complex for two reasons. First, when solving their Bellman equations, workers would need to know the future path of regulation, given the level of regulation chosen today.[1] Second, they also need to know how labor supply, and therefore prices, will respond to every chosen level of regulation. In other words, they need to know the entire shape of the aggregate transition function $F$ but, due to high-dimensionality of $F$, solving for it is difficult.
For these two reasons, the problem is computationally infeasible, and I proceed by making simplifying assumptions on the information set of individuals. The first assumption places restrictions on the beliefs of workers about the future path of regulation.

**Assumption A.1.1.** Individuals believe that the regulation elected for the next period, $\zeta^{\text{reg}}_{m,t+1}$, will persist in all subsequent periods starting from $t+1$.

The second assumption constrains agents' knowledge about the aggregate transition function $F$. In an approach similar to Krusell and Smith (1998), I make the following assumption on the relationship between labor supply and regulation.

**Assumption A.1.2.** The effect of a change in regulation on a change in labor supply of skill $s$ between period $t$ and $t+1$ is described by the following linear relationship:

$$\ln N_{ms,i} - \ln N_{ms,i-1} = \theta^s_0 + \theta^s_1 \left(\zeta^{\text{reg}}_{mi} - \zeta^{\text{reg}}_{m,i-1}\right),$$

where $i$ indexes iterations in the solution algorithm.

One difference compared to the standard Krusell-Smith algorithm is that, due to computational cost, I do not run numerous simulations to find $\theta^s_0$ and $\theta^s_1$. Instead I use the information generated when the model is solved. At every iteration toward the solution, a location experiences changes in labor supply and regulation, and I use these changes in order to estimate the relationship between labor supply and regulation. Using the estimated $\theta^s$, agents predict that, if they vote to change regulation from $\zeta^{\text{reg}}$ to $\zeta^{\text{reg}'}$, then the supply of $s$-skilled workers will change to $\ln N_{ms,i} = \ln N_{ms,i-1} + \theta^s_0 + \theta^s_1 \left(\zeta^{\text{reg}'} - \zeta^{\text{reg}}\right)$.
How reasonable are these two assumptions? Both of them imply bounded rationality of agents. The first assumption says that individuals are myopic and only think one period ahead when forming expectations about the future regulation policy path. Given that the length of the period in the quantitative model is five years, it does not seem unreasonable that, when voting in current elections, residents do not take into account their voting intentions in the elections that will take place five years from now. The second assumption says that instead of using the function $F$ to predict labor supply in the next period, workers rely on a linear approximation. It does not seem too far-fetched that, when voting, individuals ignore information such as elections in other cities, and instead rely on a simple heuristic rule that describes the relationship between regulation and labor supply.

[1] There are 972,800 types of workers: 190 cities, 2 skills, 8 ages, 40 asset grid points, 2 ownership statuses and, for an owner, 7 possible lengths of ownership. This is 5,120 types per city. Every type has a separate value function, and in every city the value functions have to be computed 20-40 times until the optimal regulation is found. The main complication emerges when for each of the 20-40 iterations I need to find the future path of regulation and labor supply that arise from optimal choices of agents.

# Appendix B

# Chapter 2

## B.1 Solving the Model

Solving the model involves finding wages, housing rents, and the initial distribution of labor across locations such that the equilibrium, as defined in section 2.2.7, holds for given parameters of the model. Unfortunately, analytical solutions do not exist due to complexity of the model and non-differentiability of the value functions.
To solve the model, I repeat the following sequence of steps until wages and housing prices in step 1 are equal to those in step 4:

1. In the first iteration, guess wages for age-2 workers, rents in every location and the tax rate $\tau$.[1] In the subsequent iterations, use wages, rents and tax rate from step 4.

2. Solve Bellman equations (2.2.12), (2.2.14), (2.2.15), and (2.2.16), and obtain decision rules for assets. In the last period a worker's value function is equal to the utility of last period's consumption. Therefore I solve the Bellman equation using backward induction starting from the last period. The fact that utility shocks are extreme value type 1 allows to avoid computation of the $I$-dimensional integral in the expectation of the value function (equation 2.2.13).[2]

3. Compute stationary distribution of workers across locations. To do this, first guess unemployment of age-1 workers of every type: $u(s, 1, i)$. Then apply the transition equations (2.2.18) and (2.2.19), and use the asset decision rules in order to obtain distribution of employment and unemployment ($n(s, a, i)$ and $u(s, a, i)$) for the fertile ages 2 to $T_f$. Next, update the guess $u(s, 1, i)$ using equation (2.2.17). Repeat the procedure until $u_t(s, 1, i) = u_{t+1}(s, 1, i)$ for all $(s, i)$.

4. Solve for new wages and rents using the updated distribution of workers across locations. Wages are computed from equation (2.2.7), while rents are found by solving equation (2.2.10). Update $\tau$ if the government budget (equation 2.2.11) is not balanced.

[1] I only need to know wages for age-2 workers. Wages for older workers can be determined as a function of age-2 wages using equation (2.2.7) as: $w(x, a, i) = \frac{\phi(a)}{\phi(2)} w(x, 2, i)$

[2] For more details, see Arcidiacono and Ellickson (2011).

## B.2 Robustness

In this section I check whether the size of the effects of relocation subsidies are robust to the choice of values for the interest rate ($r$) and the cross-location search friction ($\Delta$).
In order to check whether the value of the interest rate matters for the results I set $r = 0.02$ and recalibrate the borrowing constraint to $B = 3.12$ to match the fraction of households with negative or zero net worth. The moments of the recalibrated model remain nearly unchanged (Table B.1) and the effects of the subsidies are very similar to the results under $r = 0.04$ (Table B.2), even if slightly smaller.
Since the cross-location search friction ($\Delta$) was set in an indirect way using existing studies about cross-state job search (Section **??**), I check whether effects of the main policy would be different under a smaller and a larger value of the friction: $\Delta = 0.3$ and $\Delta = 0.5$. First, since the moments that define geographic mobility are rather sensitive to $\Delta$, I recalibrate other parameters that determine mobility ($\sigma_\varepsilon$, $\mu$, $\kappa$, and $\nu$) for both $\Delta = 0.3$ and $\Delta = 0.5$. The model fit under alternative values of $\Delta$ is presented in Table B.3. Under $\Delta = 0.3$, the relative migration to unemployment could not be matched exactly, since the offer arrival rate from other locations is too low and too many unemployed workers choose to relocate without waiting for a job offer. Table B.4 shows that the effects of subsidies are not significantly affected by the variation in $\Delta$. The effect of subsidies is somewhat muted when the friction is weak $\Delta = 0.5$, since then workers receive job offers from other locations more often and rely less on the mobility support provided by the government.

Table B.1: Model performance, 2005-2007 calibration with interest rate $r = 0.02$

| | Model | Data |
|---|---|---|
| Skill premium | 1.72 | 1.72 |
| Mean wage %, LULW city | 1.00 | 1.00 |
| Mean wage %, HULW city | 0.97 | 0.97 |
| Mean wage %, LUHW city | 1.27 | 1.28 |
| Mean wage %, HUHW city | 1.19 | 1.19 |
| Unemployment rate %, LULW city | 3.57 | 3.54 |
| Unemployment rate %, HULW city | 5.24 | 5.22 |
| Unemployment rate %, LUHW city | 3.88 | 3.86 |
| Unemployment rate %, HUHW city | 5.25 | 5.24 |
| Mobility rate, % of labor force per year | 1.91 | 1.99 |
| Mobility rate, high/low skilled | 1.31 | 1.43 |
| Mobility rate, ages 25-44 | 3.44 | 3.16 |
| Migration, (EU+UU)/(EE+UE) | 0.14 | 0.13 |
| Population, LULW city | 0.32 | 0.32 |
| Population, HULW city | 0.21 | 0.21 |
| Population, LUHW city | 0.20 | 0.20 |
| Population, HUHW city | 0.27 | 0.27 |
| Rent, LULW city | 1.00 | 1.00 |
| Rent, HULW city | 0.85 | 0.85 |
| Rent, LUHW city | 1.52 | 1.52 |
| Rent, HUHW city | 1.23 | 1.23 |
| Housing expenditure share | 0.24 | 0.24 |
| Expenditure share, high/low skilled | 0.74 | 0.74 |
| Population with negative net worth | 0.19 | 0.19 |

*Note:* I recalibrate $B$ to match the fraction of individuals with negative net worth, and keep all other parameters as in the 2005-2007 calibration. See Appendix B.2 for details.

Table B.2: Effects of moving subsidies, different interest rates

| Interest rate | 0.04 | | 0.02 | |
|---|---|---|---|---|
| Moving subsidy | 0.00 | 0.50 | 0.00 | 0.50 |
| Unemployment rate, % | 4.42 | 4.28 | 4.44 | 4.29 |
| GDP | 1.000 | 1.004 | 1.000 | 1.001 |
| Gov't expenses, % GDP | 0.826 | 0.825 | 0.830 | 0.826 |
| Consumption of goods | 1.000 | 1.001 | 1.000 | 0.995 |
| Consumption of housing | 1.000 | 0.997 | 1.000 | 0.997 |
| Mobility rate, % | 1.99 | 2.90 | 1.99 | 2.73 |
| Migration, (EU+UU)/(EE+UE) | 0.13 | 0.22 | 0.13 | 0.19 |

*Note:* The table compares the effects of a relocation subsidy that pays 1/2 of the moving cost in the economies with different interest rates both calibrated to 2005-2007. See Section 2.4.1 and Appendix B.2 for details.

Table B.3: Model performance, 2005-2007 calibrations with $\Delta = 0.3$ and $\Delta = 0.5$

| | Model $\Delta = 0.3$ | Model $\Delta = 0.5$ | Data |
|---|---|---|---|
| Skill premium | 1.72 | 1.72 | 1.72 |
| Mean wage %, LULW city | 1.00 | 1.00 | 1.00 |
| Mean wage %, HULW city | 0.96 | 0.97 | 0.97 |
| Mean wage %, LUHW city | 1.27 | 1.29 | 1.28 |
| Mean wage %, HUHW city | 1.19 | 1.20 | 1.19 |
| Unemployment rate %, LULW city | 3.55 | 3.59 | 3.54 |
| Unemployment rate %, HULW city | 5.18 | 5.29 | 5.22 |
| Unemployment rate %, LUHW city | 3.90 | 3.86 | 3.86 |
| Unemployment rate %, HUHW city | 5.31 | 5.22 | 5.24 |
| Mobility rate, % of labor force per year | 1.98 | 1.98 | 1.99 |
| Mobility rate, high/low skilled | 1.42 | 1.43 | 1.43 |
| Mobility rate, ages 25-44 | 3.51 | 3.46 | 3.16 |
| Migration, (EU+UU)/(EE+UE) | 0.18 | 0.13 | 0.13 |
| Population, LULW city | 0.32 | 0.33 | 0.32 |
| Population, HULW city | 0.21 | 0.22 | 0.21 |
| Population, LUHW city | 0.21 | 0.19 | 0.20 |
| Population, HUHW city | 0.27 | 0.26 | 0.27 |
| Rent, LULW city | 1.00 | 1.00 | 1.00 |
| Rent, HULW city | 0.85 | 0.85 | 0.85 |
| Rent, LUHW city | 1.53 | 1.49 | 1.52 |
| Rent, HUHW city | 1.23 | 1.22 | 1.23 |
| Housing expenditure share | 0.24 | 0.24 | 0.24 |
| Expenditure share, high/low skilled | 0.74 | 0.74 | 0.74 |
| Population with negative net worth | 0.19 | 0.20 | 0.19 |

*Note:* I recalibrate $\sigma_\varepsilon$, $\mu$, $\kappa$, and $\nu$ to match the four moments that describe geographic mobility for each value of the cross-location search friction: $\Delta = 0.3$ and $\Delta = 0.5$. All other parameters are kept as in the 2005-2007 calibration. See Appendix B.2 for details.

Table B.4: Effects of moving subsidies, different cross-location search frictions

| Δ | 0.3935 (benchmark) | | 0.3 | | 0.5 | |
|---|---|---|---|---|---|---|
| Moving subsidy | 0.00 | 0.50 | 0.00 | 0.50 | 0.00 | 0.50 |
| Unemployment rate, % | 4.42 | 4.28 | 4.43 | 4.27 | 4.44 | 4.33 |
| GDP | 1.000 | 1.004 | 1.000 | 1.005 | 1.000 | 1.003 |
| Gov't expenses, % GDP | 0.826 | 0.825 | 0.827 | 0.816 | 0.830 | 0.834 |
| Consumption of goods | 1.000 | 1.001 | 1.000 | 1.002 | 1.000 | 1.000 |
| Consumption of housing | 1.000 | 0.997 | 1.000 | 0.998 | 1.000 | 0.998 |
| Mobility rate, % | 1.99 | 2.90 | 1.98 | 2.80 | 1.98 | 2.98 |
| Migration, (EU+UU)/(EE+UE) | 0.13 | 0.22 | 0.18 | 0.20 | 0.13 | 0.27 |

*Note:* The table compares the effects of a relocation subsidy that pays 1/2 of the moving cost in the economies with different cross-location search frictions all calibrated to 2005-2007. See Section 2.4.1 and Appendix B.2 for details.

# Appendix C

# Chapter 3

## C.1 Data on Managerial Incomes

Table C.1: Data Sources

| Country | Years | Source | No. of Obs. |
|---|---|---|---|
| Australia | 1995, 2001, 2003, 2008, 2010 | LIS (Survey of Income and Housing Costs) | 34,202 |
| Austria | 2004-2012 | EU-SILC | 44,426 |
| Belgium | 2004-2011 | EU-SILC | 37,231 |
| Canada | 1981, 1991, 2001 | IPUMS-International (Canadian Census) | 652,124 |
| Denmark | 2004-2012 | EU-SILC | 59,241 |
| Finland | 2004-2010, 2012 | EU-SILC | 97,390 |
| France | 2004-2007, 2009-2010, 2012 | EU-SILC | 65,423 |
| Germany | 2005-2012 | EU-SILC | 76,978 |
| Iceland | 2004-2010, 2012 | EU-SILC | 30,181 |
| Ireland | 2004-2010 | EU-SILC | 24,015 |
| Israel | 2001, 2005, 2007, 2010 | LIS (Household Expenditure Survey) | 22,316 |
| Italy | 2007-2010, 2012 | EU-SILC | 89,420 |
| Luxembourg | 2004-2010, 2012 | EU-SILC | 32,105 |
| Netherlands | 2005-2010, 2012 | EU-SILC | 58,233 |
| Norway | 2004-2010, 2012 | EU-SILC | 49,038 |
| Spain | 2006-2012 | EU-SILC | 77,196 |
| Sweden | 2004-2010, 2012 | EU-SILC | 53,589 |
| Switzerland | 2011-2012 | EU-SILC | 13,105 |
| UK | 2005-2010, 2012 | EU-SILC | 47,197 |
| US | 1990, 2000, 2005, 2010 | IPUMS (US Census and ACS) | 10,928,272 |

Table C.2: Managerial Occupations

| |
|---|
| Australia |
| *Before 2001, International Standard Classification of Occupations (ISCO-88), Codes 11-13* |
| Legislators, senior officials and managers |
| Corporate managers |
| Managers of small enterprises |
| *After 2001, ASCO, occupation code 1* |
| Managers and administrators |
| |
| Austria, Belgium, Canada, Denmark, Finland, France, Germany, Iceland, Ireland |
| Israel, Italy, Luxembourg, Netherlands, Norway, Spain, Sweden, Switzerland, UK |
| *International Standard Classification of Occupations (ISCO-88), Codes 11-13* |
| Legislators, senior officials and managers |
| Corporate managers |
| Managers of small enterprises |
| |
| US |
| *IPUMS-USA 1990 Occupation Codes 004-022* |
| Chief executives and public administrators, Financial managers, Human resources and labor relations managers, Managers and Specialists in marketing, advertising, and public relations, Managers in education and related fields, Managers of medicine and health occupations, Postmasters and mail superintendents, Managers of food services and lodging occupations, Managers of properties and real estate, Funeral directors, Managers of service organizations, Managers and administrators |

## C.2 Balanced Growth

Along a balanced growth path (i) growth rates are constant; (ii) the growth rate in output equals the growth rate in labor and managerial income; (iii) growth in aggregate skill investment is the same as the growth rate in output; (iv) the capital-output ratio is constant; (v) the fractions of managers and workers are constant (i.e. $z^*(t) = z^*$ for all $t$); (vi) factor prices are constant.
We find the growth rate in output per person ($g$) and initial managerial skills ($g_z$) consistent with (i)-(vi), given a growth rate in exogenous productivity ($g_A$). Specifically, we show that there is a balanced growth path if and only if initial managerial skills grow at a specific rate determined by exogenous productivity growth.
From the properties of the plant's technology, it follows that

$$1 + g = (1 + g_A)(1 + g_z)^{1-\gamma}(1 + g_k)^{\alpha\gamma},$$

where $g_k$ stands for the growth rate of capital per person. It follows that

$$1 + g = (1 + g_A)^{\frac{1}{1-\alpha\gamma}}(1 + g_z)^{\frac{1-\gamma}{1-\alpha\gamma}} \tag{C.2.1}$$

We proceed now to find the rate of growth of managerial skills that is consistent with a balanced-growth path. We denote by $g_z^*$ such growth rate. Note that if such path exists, then the age profile is shifted by a time-invariant factor $(1 + g_z^*)$. That is,

$$\frac{z_j(t+1)}{z_j(t)} = (1 + g_z^*)$$

for all $j = 1, ...J_R - 1$. It follows that we can infer the value of $g_z^*$ from the first-order conditions for skill investments of two cohorts of age $j \leq J_R - 2$, at two consecutive dates. In particular, the first-order condition for decisions at the penultimate period of the working life cycle must hold along a balanced-growth path. From (3.3.11), it follows:

$$\left(\frac{1}{1+g_z^*}\right)^{\theta_1}\left(\frac{1}{1+g}\right)^{\theta_2-1} = (1 + g_A^*)^{\frac{1}{1-\gamma}}\left(\frac{1}{1+g}\right)^{\frac{\gamma(1-\alpha)}{1-\gamma}}. \tag{C.2.2}$$

In deriving the expression above, we used the fact that along a balanced growth path, the rate of return is constant and that the growth in output per capita, $g$, equals the growth rate in skill investments and the growth rate in wage rates. Solving for $g_z^*$ in (C.2.2), we obtain:

$$1 + g_z^* = (1 + g)^{\frac{\gamma(1-\alpha)+(1-\theta_2)(1-\gamma)}{\theta_1(1-\gamma)}}\left(\frac{1}{1+g_A}\right)^{\frac{1}{\theta_1(1-\gamma)}} \tag{C.2.3}$$

Substituting (C.2.3) in (C.2.1), after algebra we obtain

$$1 + g = (1 + g_A)^{\psi},$$

where $\psi$

$$\psi \equiv \frac{1-\theta_1}{\gamma(1-\alpha)+(1-\theta_2)(1-\gamma)-\theta_1(1-\alpha\gamma)}. \tag{C.2.4}$$

**Comments** Several points are worth noting from the expression above. First, there is balanced growth path with positive growth in per capita output as long as $\theta_1 \in [0,1)$. Second, all the same, the growth rate in output per capita increases with $\theta_2$: as the importance of investments in the production of new skills increases, the growth rate in output per capita increases as well. Indeed, as $\theta_2 \to 0$,

$$\psi \to \frac{1}{1-\alpha\gamma}.$$

That is, the growth rate approaches the growth rate with exogenous skill investments given by the reciprocal of one minus the capital share.
Finally, as the span-of-control parameter approaches 1,

$$\psi \to \frac{1}{1-\alpha},$$

which results in the growth rate of a standard economy with constant returns in capital and labor.

## C.3 Occupational Transitions

In the benchmark economy presented in detail in Section 3.3, each individual chooses his/her occupation, whether to be a worker or a manager, at the start of his/her life and this decision is *irreversible*. In this Appendix, we first document facts on transitions between managerial and non-managerial occupations for the U.S., and then build and calibrate a model economy that allows agents to switch between occupations. Finally, we study, as we did in sections 3.5.1 and 3.5.2, the effects of changes in economy-wide productivity ($\bar{A}$) and the size dependence of distortions.

### C.3.1 Data on Occupational Transitions

In order to compute transitions between managerial and non-managerial occupations in the United States, we use data from the Outgoing Rotation Groups of the Current Population Survey (CPS) for 1990-2010 period. Every household (address) that enters the CPS is interviewed for 4 consecutive months, then ignored (rotated out) for 8 months, and then interviewed again (rotated in) for 4 more months. As a result, it is possible to have observation on a subset of CPS sample that is one year apart. We follow a standard matching procedure, specified in Shimer (2012), based on matching households with the same identification code, as long as household members' characteristics (age, sex, race and education) are consistent between two points in time. The sample consists of individuals aged 25-64 who work at least 30 hours a week.

Based on matched households, we compute the fraction of individuals between ages 25-29, 30-34,..., 60-64 who transit from a managerial (non-managerial occupations) to a non-managerial (managerial) occupation within a year. A transition from managerial (non-managerial) to non-managerial (managerial) occupation occurs if in month $t$ a worker reports an occupation that belongs to the set of managerial (non-managerial) occupations, while in month $t + 12$ he/she reports an occupation that belongs to the set of non-managerial (managerial) occupations. The classification that we use to distinguish between managerial and non-managerial occupations is detailed in Section 2. If a worker is not observed or does not report any occupation in the year, he is excluded from the sample we use to calculate the transitions. We report average yearly transitions for 1990-2010 period.

Figure 1 shows the transitions between occupations in our data. As the figure shows, there are significant transitions between occupations from one year to the next. Each year about 4-5% of individuals with a non-managerial occupation move to an managerial occupation, while a much larger fraction, 40-50%, of individuals with a managerial occupation moves to a non-managerial occupation.

Transitions between managerial and non-managerial work can naturally change the fraction of individuals engaged in managerial work at different ages. To assess these potential changes, we compute the fraction of managers using the U.S. Census and ACS; the same data sets that we used to calculate managerial and non-managerial income profiles in Section 2. We calculate the fraction of managers averaged across four years (1990, 2000, 2005, and 2010). The fraction of managers grows with age in the first part of the working life cycle, and then becomes approximately constant. The fraction of individuals with a managerial occupation between ages 25-29 and 45-49 increases from about 7% to 11.8%. After that, the fraction of managers is relatively constant until the retirement age.

### C.3.2 Model

Consider now the following version of the model economy described in Section 3. Each individual is born with a managerial ability $z$, and individuals have access to a production technology to increase their managerial ability. This technology maps the current managerial ability and investment in human capital into a managerial ability level next period.

We introduce two changes into the basic model. First, we assume that accumulation of managerial skills is *risky* as in Huggett, Ventura and Yaron (2011). At the end of each period, all individuals receive a random shock, denoted by $\varepsilon$, that determines their level of skills next period in conjunction undepreciated skills and the production of new skills. In particular for a $j$-years old individual with a current skill level $z$ and investment $x$, the next period's skill level is given by

$$z' = \varepsilon\left[(1-\delta_z)z + B(j)z^{\theta_1}x^{\theta_2}\right].$$

Second, we allow both managers and workers to accumulate managerial human capital. In particular, we assume that at the start each period, all individuals, managers ($M$) and workers ($W$), decide whether to be a manager or a worker for that period. They make this decision *before* they observe $\varepsilon$. We assume that $\varepsilon$ is an *iid,* across time and individuals, shock distributed according to a cumulative distribution function $G_o(\varepsilon)$, $o \in \{W, M\}$. Once the individuals make their occupation choice, they decide how much to consume, how much to save and how much to invest to enhance their skills, $x$. They make all these decisions again before they observe $\varepsilon$. After the investment decisions are made, $\varepsilon$ is realized and the individuals enter next period with their updated level of human capital. Then they again make an occupational choice decision and so on.

In this environment, although managerial skills do not affect the current income of workers, as they simply earn $w$, they still have an incentive to invest in their skills as a favorable $\varepsilon$ shock in the future can make them switch occupations next period. A manager, on the other hand, can decide to become a worker if his/her $\varepsilon$ was too low last period. We assume that switching occupation has no monetary or utility cost.

Consider the problem of an age-$j$ individual. At the start of the of the period, given his current skills ($z$) and assets ($a$), this individual decides whether to be a manager to a worker:

$$V(a,z,j) = \max\left\{V^M(a,z,j), V^W(a,z,j)\right\}.$$

The value of being a manager $V^M(a,z,j)$ is given by

$$V^M(a,z,j) = \max_{c,a',x}\left\{u(c) + \beta\int V(a', z'(\varepsilon), j+1)dG_M(\varepsilon)\right\},$$

subject to

$$c + a' + x \leq \pi(z,r,w) + (1+r)a,$$

and

$$z' = \varepsilon\left[(1-\delta_z)z + B(j)z^{\theta_1}x^{\theta_2}\right],$$

where $\pi(z,r,w)$ is the profits of managers as defined by equation 6 in Section 3.1.

The value of being a worker $V^W(a,z,j)$, on the other hand, is given by

$$V^W(a,z,j) = \max_{c,a',x} \left\{ u(c) + \beta \int V(a', z'(\varepsilon), j+1) dG_W(\varepsilon) \right\},$$

subject to

$$c + a' + x \leq w + (1+r)a,$$

and

$$z' = \varepsilon \left[ (1-\delta_z)z + B(j) z^{\theta_1} x^{\theta_2} \right]$$

### C.3.3 Parameter Values

We follow the same calibration strategy as described in Section 4. In addition to the parameters listed in Table 1, we need to specify the functional forms for $G_M(\varepsilon)$ and $G_W(\varepsilon)$. We assume that both distributions are log-normal with mean zero and variances denoted by $\xi_M$ and $\xi_W$. In the model economy, these variances have implications for the fraction of managers in the labor force at each age as well as the relative age-earnings profile of managers. As a result, in order to calibrate these parameters we select two new targets: i) the fraction of managers at age 60-64 relative to the fraction of managers at age 25-29 and ii) an additional moment from the age-earnings profile – the relative earnings at age 50-54 (recall that relative incomes at ages 40-44 and 60-64 were already among the targets in Table 2). Table A3 presents the calibrated parameters of the model with occupational transitions. Table A4 compares the data and the model moments. The model captures endogenously the growth in the number of managers by age. Both the model and the data, the fraction of population with fraction of individuals with a managerial occupation increases by a factor of 1.63 between ages 25-29 to 60-64. Figure 2 shows the relative age-earnings profiles of managers in the model and the data. The model matches very well the age-earnings profiles of managers.

With a few exceptions parameter values in Tables 1 and A3 are quite similar. In particular, the span of control parameter $\gamma$ is larger in the economy with occupational transitions. The volatility of skill shocks is larger for workers than it is for managers: the standard deviation for workers is $\xi_W = 0.335$ while the standard deviation for managers is $\xi_M = 0.215$. Since individuals are risk-averse and there is no explicit age-dependent preference for occupation, a smaller variance of shocks to managers' skills is needed to be consistent with the fact that the fraction of managers in the workforce grows by 63% from ages 25-29 to ages 60-64.

### C.3.4 Results

To what extent do our baseline results change when we allow occupational changes over the life cycle? We now revisit the analysis of Section 5.4 and check how the economy reacts to changes in exogenous productivity and size dependency of the distortions. We report our findings in Tables A5 and A6.

We first proceed to gradually lower the exogenous TFP ($\bar{A}$) from the benchmark value of 1 to 0.7. The effects of lower $\overline{A}$ values on aggregate output is very similar to ones we obtain for an economy without managerial transitions – compare Table 3 and Table A5. Relative earnings growth declines with a reduction of economy-wide productivity across steady states, although by a smaller magnitude than under the benchmark model.

These findings show the interaction of opposing effects. On the one hand, in the model economy with occupational transitions, individuals have an additional incentive to invest in skills given by skill-accumulation risk and the occupational choice it facilitates. As a result, skill investment does not decline as rapidly in response to reduction in $\bar{A}$ as in the baseline model – compare Table 3 and Table A5. Therefore, the response of managerial quality and relative earnings growth to exogenous productivity is more muted than in the baseline analysis. On the other hand, the fraction of managers in the labor force is almost constant for all levels of $\bar{A}$, whereas it rises slightly in the baseline model. The combination of these effects results in the response of output to $\bar{A}$ which is almost identical to the one in the baseline model.

We then gradually increase the size dependency of the distortion ($\tau$) from the benchmark value of 0 to 0.08. The effects on output, mean establishment size, relative earnings growth, fraction of managers, and managerial quality are very similar to those found for the baseline model – compare Table 4 and Table A6. As in the experiment with $\bar{A}$, the response of skill investment is much smaller compared to the baseline model. Clearly, size-dependent distortions reduce managers' incentives to invest in skills in order to earn higher managerial rents. However, individuals still use skill investment as an insurance against negative skill shocks. On top of that, given the option value of an occupational switch, workers aspiring to become managers keep investing in skills even at high levels of $\tau$.

Table C.3: Parameter Values (annualized)

| Parameter | values |
|---|---|
| Population Growth Rate ($n$) | 0.011 |
| Productivity Growth Rate ($g$) | 0.025 |
| Depreciation Rate ($\delta$) | 0.040 |
| Importance of Capital ($\alpha$) | 0.386 |
| Returns to Scale ($\gamma$) | 0.844 |
| Mean Log-managerial Ability ($\mu_z$) | 0 |
| Dispersion in Log-managerial Ability ($\sigma_z$) | 3.01 |
| Discount Factor ($\beta$) | 0.931 |
| Skill accumulation technology ($\theta$) | 0.862 |
| Skill accumulation technology ($\delta_\theta$) | 0.067 |
| Skill accumulation technology ($\theta_1$) | 0.686 |
| Skill accumulation technology ($\theta_2$) | 0.461 |
| Skill accumulation technology ($\delta_z$) | 0.008 |
| Std deviation of skill shocks, managers ($\xi_M$) | 0.215 |
| Std deviation of skill shocks, workers ($\xi_W$) | 0.335 |

Note: Entries show model parameters calibrated for the model with occupational transitions. See text for details.

Table C.4: Empirical Targets: Model and Data

| Statistic | Data | Model |
|---|---|---|
| Mean Size | 17.9 | 17.7 |
| Capital Output Ratio | 2.33 | 2.33 |
| Relative Earnings Growth ($\hat{g}$) (40-44/25-29) | 0.17 | 0.16 |
| Relative Earnings Growth ($\hat{g}$) (50-54/25-29) | 0.22 | 0.23 |
| Relative Earnings Growth ($\hat{g}$) (60-64/25-29) | 0.22 | 0.22 |
| Fraction of Managers (60-64/25-29) | 1.63 | 1.63 |
| *Fraction of Establishments* | | |
| 1-9 workers | 0.725 | 0.757 |
| 10-20 workers | 0.126 | 0.108 |
| 20-50 workers | 0.091 | 0.076 |
| 50-100 workers | 0.032 | 0.028 |
| 100+ workers | 0.026 | 0.031 |
| *Employment Share* | | |
| 1-9 workers | 0.151 | 0.163 |
| 10-20 workers | 0.094 | 0.092 |
| 20-50 workers | 0.164 | 0.142 |
| 50-100 workers | 0.128 | 0.120 |
| 100+ workers | 0.462 | 0.483 |

Note: Entries show the empirical targets used in the quantitative analysis and the model's performance in the model with occuppational transitions. The fraction of establishments with 1-9 and 100+ workers, and the employment shares with 1-9 and 100+ workers are explicit targets. See text for details.

Table C.5: Effects of Economy-Wide Productivity

| Economy-Wide Productivity | $\overline{A} = 1$ | $\overline{A} = 0.9$ | $\overline{A} = 0.8$ | $\overline{A} = 0.7$ |
|---|---|---|---|---|
| Statistic | | | | |
| Output | 100 | 84.5 | 68.6 | 55.6 |
| Mean Size | 17.7 | 17.7 | 17.6 | 17.3 |
| Investment in Skills | 100 | 93.5 | 85.9 | 80.8 |
| Investment in Skills (% Output) | 8.1 | 8.9 | 10.1 | 11.7 |
| Number of Managers | 100 | 99.7 | 100.5 | 102.0 |
| Managerial Quality | 100 | 98.0 | 94.6 | 91.2 |
| Employment Share (100+) | 0.48 | 0.48 | 0.47 | 0.46 |
| Relative Earnings Growth ($\hat{g}$) | 0.23 | 0.19 | 0.17 | 0.10 |

Note: Entries show the effects on displayed variables associated to exogenous reductions in the level of economy-wide productivity ($\bar{A}$) across steady states. Column 2 reports benchmark values ($\bar{A} = 1$). Columns 3-5 report the changes emerging from reducing $\bar{A}$ below the benchmark value. See text for details.

Table C.6: Effects of Size-Dependent Distortions

| Size Dependency ($\tau$) | 0 | 0.02 | 0.04 | 0.06 | 0.08 |
|---|---|---|---|---|---|
| Tax Wedge $\left(\frac{1-T(5\overline{y})}{1-T(y)}\right)$ | 1 | 0.97 | 0.94 | 0.91 | 0.88 |
| Statistic | | | | | |
| Output | 100.0 | 93.0 | 83.7 | 78.6 | 73.3 |
| Mean Size | 17.7 | 13.0 | 10.1 | 8.1 | 6.8 |
| Investment in Skills | 100.0 | 87.1 | 78.6 | 75.1 | 72.8 |
| Investment in Skills (% Output) | 8.1 | 7.5 | 7.6 | 7.7 | 8.0 |
| Number of Managers | 100.0 | 136.1 | 174.6 | 217.5 | 261.6 |
| Managerial Quality | 100.0 | 72.2 | 54.9 | 43.7 | 36.0 |
| Employment Share (100+) | 0.48 | 0.34 | 0.22 | 0.13 | 0.07 |
| Relative Earnings Growth ($\hat{g}$) | 0.23 | 0.10 | 0.02 | -0.01 | -0.05 |

Note: Entries show the effects on displayed variables associated to size-dependent distortions across steady states. Column 2 reports benchmark values ($\tau = 0$). Columns 3-6 report the changes emerging from increasing the size dependency of distortions. See text for details.

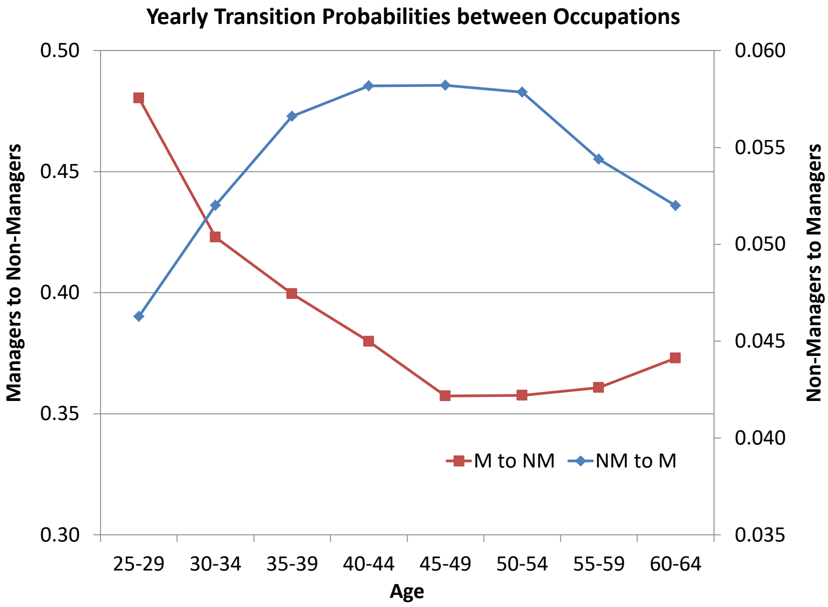



Figure C.1

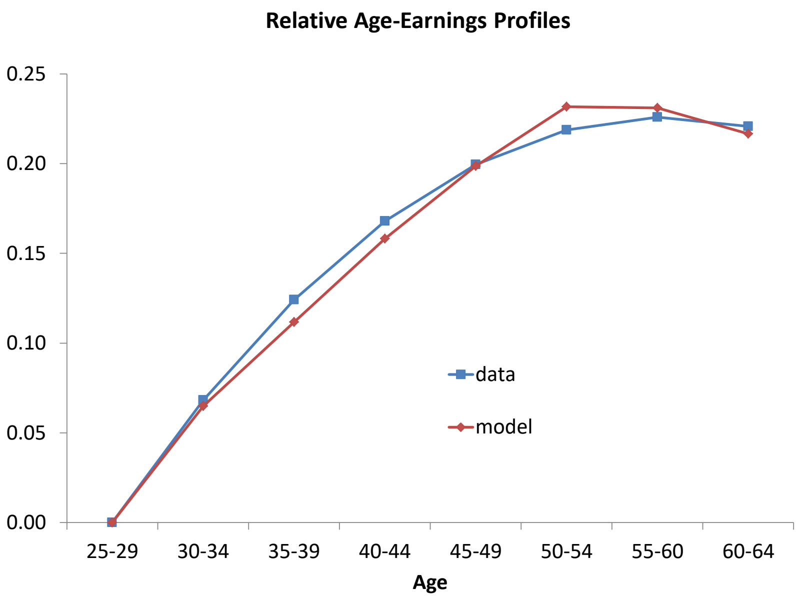



Figure C.2