Essays on Urban and International Economics

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Dedication

To my parents, Limei Jiang and Yuxin Li, who made this possible.

Abstract

My dissertation consists of three chapters. The first two chapters are about regional and urban economics, focusing on the cross section of cities. The third chapter is on international economics. In particular, sudden stop in emerging countries is examined.

In the first chapter, I study housing prices and the comparative advantage of cities. The spatial concentration of economic activity varies substantially across U.S. cities. In addition, cities with larger shares of skill-intensive industries have higher housing prices. Existing theories, however, have almost entirely focused on the relationship between city size and industrial composition. This chapter proposes a theory of cities that relates housing prices, spatial sorting, and comparative advantage. There are two ex-ante identical cities and a continuum of heterogeneous individuals, as well as a continuum of tradable goods, which differ in their dependence on local skill-intensive differentiated input components. Each individual chooses an occupation and a location according to her productivity. Cross-city heterogeneity arises endogenously through the choices made by freely mobile individuals. In any stable equilibrium, cities organize themselves into specializing in different sets of tradable goods. Empirically, I find support for my model's predictions about the cross section of cities. I extend the model to study the equilibrium effects of two types of policies: policies that attract skilled workers to particular regions, and policies that increase housing supply. I find that both types of policies have positive impacts on local productivity and income, and hence will encourage the growth of cities.

The second chapter provides a spatial explanation for cross-city price differences. Large cities are more expensive than small cities and the price differences are larger in non-tradable service goods but smaller in tradable manufacturing goods. Using detailed component data for 56 individual goods and services collected in 209 U.S. cities in 2010, I find that a one log-unit rise in city size is associated with a 3.4% increase in non-tradable price index but only a 1.2% increase in tradable price index. This chapter proposes a spatial model to explain why relative price of non-tradable goods is higher in large cities. There are two sectors: tradable manufacturing sector, and nontradable service sector. An explicit internal structure of the city is introduced: the service sector locates closest to the center, followed by the manufacturing sector, then by residents. Locations closer

to the center have a higher land price but a lower transport or commuting cost. In equilibrium, all agents in the city face this trade-off and choose their optimal location. The model provides a theoretical microeconomic foundation for the large empirical literature on cross-city price differences.

The third chapter explores the sudden stops in emerging economies. Financial crises are accompanied by a large fall in total factor productivity. In emerging economies, about 40% of domestic credits are provided by banks. Previous theories have largely focused on the impact of an exogenous change in domestic interest rate on the economy. In this chapter, I explore the role of banks' intermediation in exacerbating the allocative inefficiency. I build a small open economy model in which banks are the only domestic agents with access to international capital markets. During sudden stops, a shock to the world interest rate will decrease banks' credit supply and raise domestic interest rate on loans. Firms, with working capital financing needs, will experience an increase in the cost of production. This worsens the misallocation and generates an endogenous fall in TFP and output. The model is calibrated to Mexico before the 1995 crisis. It can explain more than half of the fall in TFP.

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Chapter 1

Housing Prices and the Comparative Advantage of Cities

1.1 Introduction

The spatial concentration of economic activity varies substantially across U.S. cities. San Jose hosts the production of the most skill-intensive goods, computer and electronic products, while the largest sector in San Antonio is food manufacturing. In addition, although these two cities are of similar size, the housing price in San Jose is about twice as high as in San Antonio. One reason that San Jose has one of the most expensive housing markets in the U.S. is that it has more skilled workers. Why do workers locate in cities that are expensive to live in? What is the relationship between housing prices and skill distribution across cities? Do cities with comparative advantage in skill-intensive sectors exhibit high housing prices? This paper attempts to answer these fundamental questions on the spatial variation of housing prices, skill distribution, and industrial specialization.

Traditional models, pioneered by Henderson (1974), almost entirely emphasize the relationship between city size and industrial composition. Not until recently have economists became interested in spatial sorting of individuals across cities (e.g., Davis and Dingel, 2012). By assuming only one tradable good produced in all cities, these new models on sorting cannot explain industrial specialization. In addition, little attention has been drawn upon the relation between housing prices and the comparative advantage of cities.[1] This paper integrates housing prices, spatial sorting, and industrial specialization in a theory of cities that can be used to understand the effects of government policies targeted to specific regions.

More specifically, I develop a model with two *ex-ante* homogeneous cities. Each city is endowed with a fixed amount of land, owned by competitive landowners who convert each unit of land to one unit of housing. There is a continuum of final tradable goods, each of which is assembled by combining homogeneous labor-intensive components and a composite of differentiated skill-intensive components, according to a Cobb-Douglas technology. The final goods can be freely traded between the two cities and they differ by the share of skill-intensive components, the production of which features monopolistic competition, as in Dixit and Stiglitz (1977). There is a continuum of heterogeneous individuals, each choosing an occupation - to be either a team leader or a worker - and a location. More skilled individuals become team leaders, each of whom designs one variety of skill-intensive components and leads a group of workers to produce. Less skilled individuals become workers and can produce both labor and skill intensive components. Each individual consumes final goods and housing, and chooses her location to maximize utility.

Cross-city heterogeneity arises endogenously through the choices made by freely mobile individuals. Workers are equally productive and locate in both cities. Team leaders sort across cities according to their productivity. The city with more and/or highly skilled team leaders exhibits higher aggregate productivity and comparative advantage of skill-intensive goods. Since workers obtain the same utility everywhere, free migration of workers is then associated with a compensating differential, i.e., higher productivity in the city must be associated with a higher wage rate and hence a higher housing price. This difference in housing prices between the two cities induces the sorting of team leaders: only the most talented team leaders will be able to afford to live in the more expensive city, while less skilled team leaders are better off in the city where housing price is lower. This sorting reinforces the heterogeneity between cities: in any stable equilibrium, one city ends up having a higher housing price, more skilled team leaders, a larger share of aggregate income and population, and a comparative advantage in

[1] Throughout this paper, I use the housing price as an approximation for urban cost. It turns out that cross-city price differences can be mainly explained by the housing price differences. See Appendix A for detailed data and estimations.

tradable sectors that rely more heavily on skill-intensive components.

I use the model to study the effects of government policies targeted to specific regions. Local governments invest in education and offer financial incentives to attract productive firms. These aim at raising local income by increasing the number of skilled workers. These financial incentives are pervasive (Kline and Moretti, 2013; Busso, Gregory, and Kline, 2013) and come in many forms such as cash grants, loans, and tax breaks. In addition, local land regulations such as zoning restrictions can impact the growth of cities. The limited expansion of the regions around New York, Boston, and San Francisco is attributable to stringent land-use regulations, which generally lead to high housing prices and limit the ability of workers to access the highly productive technologies available in these cities. To analyze the effects of these local policies, I extend my model to incorporate both local financial incentives and land regulations. I find that a subsidy to the team leader's income in the less productive city attracts more skilled migrants and helps the city grow. On the other hand, a policy that increases the housing supply makes the productive city become even more productive as more skilled individuals move there because of the affordable housing. Both policies have positive effects on local productivity and income.

Empirically, I find support for my model's predictions about the cross section of cities. As in the traditional trade model, each city produces a subset of goods. By looking at the U.S. data, I find that cities with high housing prices specialize in producing more skill-intensive goods, which is exactly what my model predicts. In addition, the model's result regarding the spatial sorting of team leaders also implies an empirical pattern in the top-tail distribution of skills: the skill level in the top percentiles of cities with high housing prices in general is higher than anywhere else. Therefore, cities such as New York, San Jose, and San Francisco are the ultimate places of top CEOs, top lawyers, top engineers, and many other professionals. This allows me to conclude that the observed pattern of skills, the fatter tails at the top of the distribution, supports the spatial sorting of team leaders in my model. Finally, I look at the empirical evidence on the effects of the two types of policies examined in this paper: increasing housing supply and local financial incentives. Data show that cities with highly regulated land markets and those with more skilled workers exhibit higher housing prices, income, and population. This is consistent with my model's prediction that both types of policies have positive effects on the growth of cities.

The model matches a broad set of facts from the empirical literature. It generates asymmetric outcomes without relying on assumptions of asymmetries in workers' mobility or cities' fundamental characteristics. These asymmetric differences are accompanied by cross-city differences in wages, housing prices and productivity (Glaeser, 2008; Moretti, 2012). Recent work by Combes, Duranton, and Gobillon (2008) and Gibbons, Overman, and Pelkonen (2010) provides evidence that spatial wage variation is attributable to spatial sorting of heterogeneous workers. Bacolod, Blum, and Strange (2009) and Glaeser and Resseger (2010) find that more talented individuals move to cities where urban costs are higher, which is a prediction of my model. In particular, Eeckhout, Pinheiro, and Schmidheiny (2014) document the fact that skill distribution has thicker tails in large cities, which supports my model's prediction that the skill level at the top of the skill distribution is higher in cities where housing prices are high.

A distinguishing aspect of the theory is that it features a rich set of elements in a model of cities - housing prices, industrial specialization, individual's occupational choice, and spatial sorting - which has not been studied before. The most closely related paper is Davis and Dingel (2012), who develop a system of cities model in which idea exchange is an explicit economic decision. Their model also features occupational choice and spatial sorting: skilled workers produce tradable goods and unskilled workers produce non-tradable goods. In their paper, skilled workers devote time to exchange ideas with each other to raise their productivity, and highly skilled workers benefit more by sorting to large cities because these cities exhibit better learning environments. Since there are only one tradable good and one non-tradable good, their model does not capture the industrial specialization across cities. By having a continuum of final tradable goods, my model yields the spatial pattern of industries.

The paper is related to several strands of the literature. The model builds on and expands the large theoretical literature in international trade on comparative advantage. It extends traditional Ricardian and Heckscher-Ohlin models in that comparative advantage is determined endogenously and depends on the available variety of local differentiated input components. This extension is more in line with Matsuyama (2013), who proposes a symmetric-breaking model of trade with a large but finite number of *ex-ante* identical countries. In his paper, productivity differences across countries arise endogenously through firms' entry and he shows that in equilibrium, countries sort themselves into specializing in different sets of tradable goods. My approach is similar, with the difference that the endogenous comparative advantage arises from the spatial sorting of individuals.

The model also contributes to the literature on the specialization of regions in economic geography. Cities with high housing prices produce those goods that are more skill intensive. This kind of specialization has not been studied before, as prior theories of cities have focused on the two extreme cases: either a city contains only one industry, or it hosts all the modeled industries. One exception is Davis and Dingel (2013), who suggest an urban hierarchy in terms of sectors and skills. In their theory, large cities produce all of the goods that are produced in smaller cities plus additional skill-intensive items that are not made in smaller cities. Namely, larger cities have a strict superset of goods produced in smaller cities. My model does not yield such a hierarchy: each city produces a different set of goods and there are no goods produced in both cities. With this type of specialization, the variation of industrial composition across cities becomes clear: some cities produce skill-intensive goods while others produce labor-intensive goods. Moreover, the model is related to the work on the pattern of specialization that emerges from symmetric fundamentals.[2] Krugman and Venables (1995), for example, develop a model in which there is no inherent difference among countries, but the world economy organizes itself into a core-periphery pattern. In their model, however, factors of production are immobile.

The theoretical literature about the spatial sorting across cities is more limited. In recent work, Behrens, Duranton, and Robert-Nicoud (2014) look at the complementarities between agglomeration, sorting, and selection to explain why large cities are more productive. In particular, they construct an equilibrium with a system of talent-homogeneous cities. They model location choice and occupational choice in two steps: each individual chooses where to locate based on her talent, then upon moving to a city, each individual draws a "serendipity", which, together with her talent, determine her occupational choice. My paper differs from theirs in that occupational choice and location choice occur simultaneously. Another paper on sorting by Eeckhout, Pinheiro,

[2]See Fujita, Krugman, and Venables (1999) and Combes, Mayer, and Thisse (2008) in economic geography and Ethier (1982a), Helpman (1986), and Matsuyama (1996) in international trade.

and Schmidheiny (2014) shows that the different degrees of complementarities between the skills of workers determine the equilibrium skill distribution across cities. More specifically, large cities disproportionately attract both high and low skilled workers when skill complementarities are stronger between more extreme skills. My findings are consistent with their theory, in that cities with high housing prices have fat tails at the top of the skill distribution. All of these existing papers emphasize sorting between cities of different sizes, while my paper investigates sorting between cities with different housing prices.

Finally, the model complements the recent work that estimates the effects of local policies that impact the growth of cities. Gaubert (2014) studies the sorting of heterogeneous firms across locations: firms' location choice is driven by a trade-off between gains in productivity, local level of input prices, and the existence of local subsidies. She then uses the estimated model to quantify the aggregate effects of local subsidies and land regulations. My model differs in that I look at the sorting of heterogeneous individuals and I analyze the local effects of the two types of policies. These local effects have been studied in recent empirical work. Busso, Gregory, and Kline (2013) assess the efficiency of the federal program, Empowerment Zones, which offers grants, tax credits, and other benefits to areas that have experienced poverty and/or high emigration[3]; Mayer, Mayneris, and Py (2012) empirically study the impact of a French enterprise zones program on establishment location decisions.

In what follows, Section 1.2 introduces the baseline model, in which land supply is fixed in each city and no local government policies are involved. Section 1.3 derives multiple equilibria analysis and conducts a numerical exercise of solving the asymmetric equilibrium. Section 1.4 presents two extensions of the baseline model: introducing a housing construction sector and a local subsidy on team leader's income. It also reports results from the two policy experiments. Section 1.5 presents detailed empirical facts on industrial specialization and skill distribution across cities with different housing prices, and studies the effects of the two types of policies empirically. Finally, Section 1.6 concludes.

[3]Glaeser and Gottlieb (2008) also study the economic impact of Empowerment Zones, among other things.

1.2 The Model

The economy consists of two *ex-ante* identical cities: City 1 and City 2. Each city is endowed with a fixed amount of land, which is normalized to 1. Land is owned by competitive landowners outside the economy, who convert each unit of land to one unit of housing. There is a continuum of individuals, the mass of which is L; each choosing an occupation, to be either a team leader or a worker, and a location, either City 1 or City 2. Individuals are heterogeneous in their productivity φ, with cumulative distribution function $F(\varphi)$. Following the literature, I assume that the productivity φ is Pareto distributed with a lower bound $\underline{\varphi}$ and shape parameter δ. There is a continuum of final tradable goods sectors $s \in [0,1]$, each of which is different in its share of two types of local components: homogeneous labor-intensive components and a continuum of skill-intensive components. Labor-intensive components are produced by workers only, while skill-intensive components are produced by workers using the technology provided by team leaders. Throughout this paper, I assume zero transport costs and no other impediments to trade.

1.2.1 Final Goods Sectors

Each final good $s \in [0,1]$ is costlessly assembled by combining labor-intensive components and skill-intensive components, according to a Cobb-Douglas production technology with constant returns to scale. Aggregate output in city $j \in \{1,2\}$ by sector s is given by

$$Y_j(s) = A_j(s) M_{E,j}(s)^{\gamma(s)} M_{L,j}(s)^{1-\gamma(s)}, \tag{1.2.1}$$

where $A_j(s)$ is sector-specific scale parameter, $M_{E,j}(s)$ is the sector s demand for skill-intensive components, $M_{L,j}(s)$ is the sector s demand for labor-intensive components, and $\gamma(s) \in [0,1]$ is the share of skill-intensive components used in the final production by sector s. This share of skill-intensive components in sector s, $\gamma(s)$, varies across sectors. The final tradable goods are ordered so that $\gamma(s)$ is increasing in $s \in [0,1]$. That is, higher indexed sectors rely more heavily on skill-intensive components.

The location of each sector s is determined through competition, resulting in the price $P(s)$ of each final good s equaling the lowest unit cost of production. Let $C_j(s)$ and $\mathbb{S}_j \subseteq [0,1]$ denote the unit cost of production of sector s and the set of sectors active in city j, respectively, then it holds that $P(s) = C_j(s)$ if $s \in \mathbb{S}_j$.

The differentiated skill-intensive components enter the production technology with constant elasticity of substitution $1 + 1/\varepsilon$, with $\varepsilon > 0$,

$$M_{E,j}(s) = \left[\int_{\Omega_j} x_j(i,s)^{\frac{1}{1+\varepsilon}} \, di \right]^{1+\varepsilon}, \tag{1.2.2}$$

where $x_j(i,s)$ is the amount of variety i used by sector s in city j and Ω_j is the endogenously determined set of varieties of skill-intensive components produced in city j. Aggregate increasing returns arise here from the productive advantage of sharing a wider variety of differentiated inputs. In other words, an increase in the labor input of sector s must be associated with more skill-intensive components, and final producers become more productive when they have access to a wider range of varieties.

1.2.2 Labor-Intensive Components

The local labor-intensive components are produced by workers. Labor is the only input. This market is competitive and firms need one unit of labor to produce each unit of output.

$$P_{L,j} = w_j$$

is the condition that price equals marginal cost, where w_j is the wage rate of workers.

1.2.3 Skill-Intensive Components

As in Ethier (1982b), local skill-intensive components production is characterized by monopolistic competition *à la* Dixit and Stiglitz (1977). Each team leader designs one variety and leads a team of workers to produce. Therefore, Ω_j, the set of varieties, also denotes the set of team leaders and i refers to a team leader, or equivalently, the variety she produces. Output of variety i in city j is

$$x_j(i) = \varphi_j(i) l_j(i), \tag{1.2.3}$$

where $l_j(i)$ is the number of workers needed for the production of variety i and $\varphi_j(i)$ is the team leader i's productivity.

Minimizing production costs in the final goods sectors subject to technology in (1.2.1) and (1.2.2) gives the demand for skill-intensive components by sector s:

$$x_j(i,s) = \left[\frac{p_j(i)}{\mathbb{P}_j}\right]^{-\frac{1+\varepsilon}{\varepsilon}} M_{E,j}(s), \tag{1.2.4}$$

where $\mathbb{P}_j \equiv \left[\int_{\Omega_j} p_j(i)^{-\frac{1}{\varepsilon}} di\right]^{-\varepsilon}$ is the price index of the aggregate of skill-intensive components in city j. The price for each variety i in city j is then

$$p_j(i) = (1+\varepsilon)\,\frac{w_j}{\varphi_j(i)}. \tag{1.2.5}$$

Output of variety i can then be rewritten as

$$x_j(i) = \int_{s\in\mathbb{S}_j} x_j(i,s)ds = \int_{s\in\mathbb{S}_j} \left[\frac{p_j(i)}{\mathbb{P}_j}\right]^{-\frac{1+\varepsilon}{\varepsilon}} M_{E,j}(s)ds, \tag{1.2.6}$$

Let Y be the economy-wide income excluding land rents. Equal weights of industries in preferences and the production technology of the final goods sectors then imply that two market clearing conditions, one for the final goods and the other for the skill-intensive components, are consolidated into

$$\int_{\mathbb{S}_j} M_{E,j}(s)ds = \frac{\alpha Y \int_{\mathbb{S}_j}\gamma(s)ds}{\mathbb{P}_j} = \frac{\alpha Y \Gamma_j}{\mathbb{P}_j}, \tag{1.2.7}$$

where α is the expenditure share of final goods in consumer's preference, and $\Gamma_j \equiv \int_{\mathbb{S}_j}\gamma(s)ds$ denotes the aggregate share of skill-intensive components used in the final goods production in city j. A higher Γ_j means either the set of sectors active in city j, $\mathbb{S}$, has a larger measure, or the available sectors in city j are more dependent on the skill-intensive components, i.e., larger γ's. Hence, Γ_j measures the market size or the demand of skill-intensive components in city j. Then $\alpha Y\Gamma_j$ represents the sum of expenditures for the skill-intensive components in city j, which is also the consumer demand. Using this equation and (1.2.5), I can rewrite (1.2.6) as

$$x_j(i) = \left(\frac{\varphi_j(i)}{\Phi_j}\right)^{1+\frac{1}{\varepsilon}} \frac{\alpha Y\Gamma_j}{\mathbb{P}_j}, \tag{1.2.8}$$

where $\Phi_j = \left[\int_{\Omega_j} \varphi_j(i)^{\frac{1}{\varepsilon}} di\right]^{\varepsilon}$ is the aggregate productivity in city j. Note here more team leaders in a city (i.e., a larger measure of Ω) and/or more skilled team leaders (i.e., on average larger φ's) imply a higher aggregate productivity. Using (1.2.5) and (1.2.8), the price index can be rewritten as

$$\mathbb{P}_j = \frac{(1+\varepsilon)\, w_j}{\Phi_j}. \tag{1.2.9}$$

Rather than being paid a flat wage as workers, each team leader i gets paid the profits of producing variety i, which can be written as

$$\pi_j(i) = p_j(i)x_j(i) - \frac{w_j x_j(i)}{\varphi_j(i)} = \frac{\alpha\varepsilon}{1+\varepsilon}\left(\frac{\varphi_j(i)}{\Phi_j}\right)^{\frac{1}{\varepsilon}} Y\Gamma_j. \tag{1.2.10}$$

Team leader i's income increases with the market size of skill-intensive components in city j (Γ_j). Income also depends on team leader's own productivity relative to the aggregate productivity, $\varphi_j(i)/\Phi_j$. In other words, given team leader i's own productivity, she would like to locate in a city with high demand for skill-intensive components (large Γ) and low aggregate productivity (low Φ). This combination, however, does not happen in equilibrium: large market size is associated with high aggregate productivity. Therefore, when a team leader chooses her location, she faces this tradeoff: a large market also means toughness because she has to compete with other higher skilled team leaders.

The unit production cost for final tradable good s can thus be expressed as

$$C_j(s) = \xi(s) w_j^{1-\gamma(s)} \mathbb{P}_j^{\gamma(s)} = \xi(s)\,(1+\varepsilon)^{\gamma(s)}\, w_j \Phi_j^{-\gamma(s)}. \tag{1.2.11}$$

This equation shows that, for each sector s, given w, a higher Φ (because more team leaders and/or better team leaders) will reduce the unit production cost in all tradables, which captures the productivity gains from varieties. And this productivity gain is greater for higher-indexed sectors. The comparative advantage is then captured by the ratio of the costs, $C_1(s)/C_2(s)$.

Before proceeding, note that the production process has elements of both the Ricardian and Heckscher-Ohlin models with a continuum of goods. The features that labor is the only input for the production of both skill and labor intensive components and that comparative advantage is attributable to the relative wage structure between two cities are consistent with the Ricardian model (Dornbusch, Fischer, and Samuelson, 1977). Moreover, final goods are indexed in order of increasing skill intensity, which is more similar to the Heckscher-Ohlin model (Dornbusch, Fischer, and Samuelson, 1980).

1.2.4 Individuals

Individuals are *ex-ante* heterogeneous in their productivity φ. Depending on this productivity, each individual chooses her occupation and location freely to maximize her utility. The decisions of occupation and location occur simultaneously, nonetheless I will start the discussion of occupational choice first. Let $U_j(\varphi)$ and $y_j(\varphi)$ denote the utility and income of an individual with productivity φ residing in city j.

Occupational Choice

Suppose that an individual chooses to reside in city j. Then she chooses the occupation to maximize her income. If she chooses to be a worker, she inelastically supplies one unit of labor. Workers are assumed to be equally productive and thus she receives a constant wage w_j. If she chooses to be a team leader, she supplies knowledge and earn $\pi_j(\varphi)$ depending on her productivity. Thus her income is given by $y_j(\varphi) = max\left\{\pi_j(\varphi), w_j\right\}$. There exists a productivity cutoff level φ_j^*, defined by $\pi_j(\varphi_j^*) = w_j$, such that all individuals with productivity above φ_j^* become team leaders and all individuals with productivity below φ_j^* become workers. Using (1.2.10), this productivity cutoff is given by

$$\varphi_j^* = \Phi_j \left(\frac{1+\varepsilon}{\alpha\varepsilon} \frac{w_j}{Y\Gamma_j} \right)^{\varepsilon}. \tag{1.2.12}$$

We can see that this cutoff is higher (or equivalently, it is harder to become a team leader) when aggregate productivity Φ is higher, since it is more difficult to compete against more or better team leaders. It is also harder to become a team leader when wage rate of workers is high (i.e., outside option is more attractive), and when Γ is low (less demand for skill-intensive components).

Residential Choice

Each individual chooses her location to maximize her utility. For the given income $y_j(\varphi)$, each individual consumes final goods and housing:

$$\begin{aligned} U_j(\varphi) = \max_{\{c_j(s,\varphi)\}_{s\in[0,1]},\, h_j(\varphi)} exp\left[\alpha \int_0^1 ln\left(c_j\left(s,\varphi\right)\right) ds\right] h_j\left(\varphi\right)^{1-\alpha}, \\ s.t. \\ \int_0^1 P(s) c_j\left(s,\varphi\right) ds + R_j h_j\left(\varphi\right) = y_j(\varphi), \end{aligned} \tag{1.2.13}$$

where α is the expenditure share of final goods in consumer's preference, $c_j\left(s,\varphi\right)$ denotes the quantity of final goods consumed by an individual with φ residing in city j, $h_j\left(\varphi\right)$ is the quantity of housing consumed, and R_j is city j's housing price. Without loss of generality, I measure the size of (a set of) sectors by the expenditure share of the goods produced in these sectors. With this indexing, the size of sectors whose γ is less than or equal to $\gamma(s)$ is equal to s, and a city's share in the economy-wide income is equal to the measure of the tradables for which the city ends up having comparative advantage in equilibrium.

The productivity composition and population size of a city are endogenously determined. The population of city j, L_j, is given by

$$L_j = \int_{\underline{\varphi}}^{\infty} L_j(\varphi) d\varphi, \tag{1.2.14}$$

where $L_j(\varphi)$ is the population with productivity φ in city j. In equilibrium, all individuals must live in a city. The adding-up constraint for each type of productivity thus requires that

$$Lf(\varphi) = L_1(\varphi) + L_2(\varphi), \qquad \forall \varphi \in [\underline{\varphi}, \infty), \tag{1.2.15}$$

where $f(\varphi)$ is the probability distribution of productivity. Equation (1.2.15) states that the mass of individuals with productivity φ across both cities must be equal to the mass of individuals with productivity φ in the population. Summing equation (1.2.15) across all productivity types then implies satisfying the full population condition of the model.

1.3 Equilibrium Analysis

I now discuss the properties and implications of the model. To help with the intuition, I start with a single-city version of the model. This can be viewed as the equilibrium allocation of a city in autarky in an economy with multiple cities.

1.3.1 Single-City (Autarky) Equilibrium

In the one-city economy, markets for final goods, the two types of components, and labor clear, and the population constraints are satisfied. The city must produce all the consumption goods in the absence of trade,

$$P(s) = C(s) = \xi(s)\,(1+\varepsilon)^{\gamma(s)}\, w\Phi^{-\gamma(s)} \qquad \forall s \in [0,1]\,,$$

and the market clearing condition for the skill-intensive components is

$$\int_0^1 \mathbb{P}M_E(s)ds = \alpha Y \int_0^1 \gamma(s)ds = \alpha Y \Gamma^A,$$

where $\Gamma^A \equiv \int_0^1 \gamma(s)ds$. In autarky, the share of skill-intensive components in aggregate income is equal to the average share of skill-intensive components across all the final goods sectors.

Labor in the city is supplied by workers, i.e., all individuals with productivity less than φ^*. City labor supply is then equal to $L^S = L\int_{\underline{\varphi}}^{\varphi^*} dF(\varphi)$. Since workers are involved in the production of both types of components, there are two sources of labor demand: sector s spends $100\,(1-\gamma(s))\,\%$ of its total revenue on labor, and each skill-intensive variety (team leader i) spends $\frac{wx(i)}{\varphi(i)}$ on labor. Therefore, labor market clearing condition gives

$$\alpha\left(1-\Gamma^A\right)Y + wL\int_{\varphi^*}^{\infty} \frac{x(\varphi)}{\varphi} dF\left(\varphi\right) = wL^S.$$

Using (1.2.8) and (1.2.9), this condition can be simplified as

$$\alpha\left(1-\Gamma^A+\frac{\Gamma^A}{1+\varepsilon}\right)Y = wL^S. \tag{1.3.1}$$

This labor market clearing condition implies that aggregate workers' income is a constant share of output. Aggregate productivity, as defined in (1.2.8), can be rewritten as

$$\Phi = \left[L \int_{\varphi^*}^{\infty} \varphi^{\frac{1}{\varepsilon}} dF(\varphi) \right]^{\varepsilon}. \tag{1.3.2}$$

Proposition 1. (Existence and Productivity Cutoff) *Given population, L, and its productivity distribution, $F(\cdot)$, the equilibrium in autarky exists, is unique, and the productivity cutoff for being a team leader does not depend on city population.*

Proof. See Appendix A. □

The intuition behind this result can be seen in equation (1.3.1). Workers (and thus team leaders) receive a constant share of city output. Hence, keeping the distribution of individual productivity constant, a city hosts the same proportion of workers and team leaders regardless of its size.

1.3.2 Two-City Equilibria

There are two classes of equilibria for the two-city economy: a symmetric equilibrium in which both cities have the same set of varieties of skill-intensive components, and an asymmetric equilibria in which this endogenous variable is different across cities. The latter are the empirically relevant class, since there is spatial variation in productivities and sets of goods produced across cities. I start with the symmetric equilibrium, however, to illustrate why it is unstable before analyzing the properties of the asymmetric equilibria.

Symmetric Equilibrium

Since my model has symmetric fundamentals, there always exists a symmetric equilibrium. In such an equilibrium, the endogenous variable, the set of skill-intensive varieties of components, Ω, is also the same in both cities. This means that both cities have the same number of team leaders and all skill types are equally represented in both cities.

Thus aggregate productivity is the same, $\Phi_1 = \Phi_2$, and both cities have the same prices, $w_1 = w_2$, and $R_1 = R_2$. In this symmetric equilibrium, which replicates the autarky equilibrium in each city, the unit production cost of each tradable good is equal across the two cities, $C_1(s) = C_2(s) \ \forall s \in [0,1]$. Therefore, consumers everywhere are indifferent as to which city they buy the goods from. In other words, the patterns of trade are indeterminate. If exactly 50% of the economy-wide income Y is spent on each city's final goods, and if this spending is distributed in such a way that the production of skill-intensive components in each city ends up receiving exactly $\Gamma^A/2$ of the economy-wide spending, then the symmetric equilibrium, in which both cities have the same set of skill-intensive components, would emerge. This equilibrium, however, is unstable in that a small perturbation that results in one city is more productive than the other ($\Phi_1 > \Phi_2$ or $\Phi_1 < \Phi_2$) will break the symmetric equilibrium.[4]

Asymmetric Equilibria

The stability of an equilibrium in a two-city model requires that the endogenous variable, Ω_j, is different across cities. To discuss the properties of such an equilibrium, suppose that City 2 has more skill-intensive varieties of components (i.e., more team leaders). Then it immediately implies that, the aggregate productivity Φ, as defined in (1.2.8), is higher in City 2, i.e., $\Phi_1 < \Phi_2$.

Comparative Advantage

Using equation (1.2.11), the relative cost of production in sector s is given by

$$\frac{C_1(s)}{C_2(s)} = \left(\frac{w_1}{w_2}\right)\left(\frac{\Phi_1}{\Phi_2}\right)^{-\gamma(s)}, \tag{1.3.3}$$

which is monotonically increasing in s. The pattern of specialization under a set of specified parameters is shown in Figure 1.1. This implies that City 1 has comparative advantage in lower-indexed goods and City 2 has comparative advantage in higher-indexed goods. There exists a threshold, S, which summarizes the specialization pattern of final goods across the two cities. Because goods are ordered in such a way that higher-indexed goods rely more heavily on skill-intensive components, City 1 produces

[4] Any microfoundations in which the city with a larger set of team leaders exhibits a higher endogenous value of Φ will result in symmetry-breaking. One example could be a perturbation on preference so that consumers prefer to buy the goods from one of the two cities.

and exports more labor-intensive goods in $[0,S)$, while City 2 produces and exports more skill-intensive goods in $(S,1]$, where $S \in (0,1)$ is defined by

$$\frac{C_1(S)}{C_2(S)} = \left(\frac{w_1}{w_2}\right)\left(\frac{\Phi_1}{\Phi_2}\right)^{-\gamma(S)} = 1. \tag{1.3.4}$$

That is, sector S has the same cost in both cities. This means that the equilibrium wage rates for workers can be expressed as

$$\frac{w_1}{w_2} = \left(\frac{\Phi_1}{\Phi_2}\right)^{\gamma(S)} < 1. \tag{1.3.5}$$

Thus, due to the higher productivity in City 2, worker's wage is higher in City 2, $w_1 < w_2$.

The endogenous comparative advantage arises from the productivity difference between the two cities. Higher productivity in City 2 will lower the cost of final tradables that use more skill-intensive components. On the other hand, since $P_{L,j} = w_j$, City 1 has comparative advantage in sectors that rely more heavily on labor-intensive components because City 1 has a lower labor cost.

Individual Behavior

There is a population of workers located in each city. In equilibrium, each of these workers obtains the same utility, so the utility maximization problem (1.2.13) implies that the spatial difference in their wage rates compensates for the spatial difference in housing prices:

$$\frac{w_1}{w_2} = \left(\frac{R_1}{R_2}\right)^{1-\alpha}. \tag{1.3.6}$$

Not surprisingly, $R_1 < R_2$, i.e., the more productive city has a higher housing price. This fact has been documented extensively in the literature. Albouy (2008) finds that for given output prices, more productive cities pay higher rents and wages.

Lemma 1. (Occupational Choice) *In any asymmetric equilibrium, the productivity cutoff for being a team leader is the same across cities. That is,* $\varphi_1^* = \varphi_2^* = \varphi^*$.

Proof. See Appendix A. □

Lemma 1 simply states that if an individual chooses to be a worker in one city, then she cannot become a team leader by changing her location. The intuition behind this result can be seen from (1.2.12). It is the outcome of two offsetting forces. City 2 has a higher aggregate productivity (Φ) and a higher wage rate (w). These capture the crowding out effects, which raise the cutoff. At the same time, the market size of the skill-intensive components (Γ) is also larger in City 2, which lowers the cutoff and captures the demand effect. It turns out that these two kinds of effects exactly offset each other in my framework. The reason behind this can be found in equation (1.2.10). The optimal pricing strategy is a proportional mark-up over wage (i.e., equation 1.2.5), due to Dixit-Stiglitz form of demand. The constant returns to scale at the level of the production of skill-intensive components ensure that cost is proportional to wage rate. Therefore, (1.2.10) implies that team leader's income, $\pi_j(\varphi)$, is proportional to worker's wage, w_j. In other words, a city with a higher w_j has a proportionally higher $\pi_j(\varphi)$. The cutoff φ^*, which is defined as $\pi_j(\varphi^*) = w_j$, thus, does not depend on j. The upper panel of Figure 1.2 shows a numerical illustration of Lemma 1.

Lemma 2. *Given her individual productivity φ, a team leader can always get higher income by locating to the more productive city. That is, $\pi_2(\varphi) > \pi_1(\varphi)$ for all φ.*

Proof. See Appendix A. □

This comes directly from Lemma 1, which states that the crowding out forces, a high Φ and a high w in City 2, exactly offset the demand effect, a high Γ. Equation (1.2.10) shows that the only forces show up in the team leader's income are Φ and Γ, and thus the demand effect in City 2 outweighs the crowding out effect. This can be seen in the upper panel of Figure 1.2, in which $\pi_2(\varphi)$ is above $\pi_1(\varphi)$ for all φ. Although team leaders can get higher income by moving to City 2, not all team leaders locate there in equilibrium, because the high housing price in City 2 makes it unaffordable for some team leaders. To see this, the indirect utility of team leaders with productivity φ who locate in city j can be expressed as

$$v_j(P, R_j, y_j) = \pi_j(\varphi) \left(\frac{\alpha}{P}\right)^{\alpha} \left(\frac{1-\alpha}{R_j}\right)^{1-\alpha}.$$

Then there exists φ^{**} such that $\varphi^{**} > \varphi^*$ and team leaders with productivity φ^{**} are indifferent to which city they reside in. The cutoff φ^{**} is defined as

$$\frac{\pi_1(\varphi^{**})}{R_1^{1-\alpha}} = \frac{\pi_2(\varphi^{**})}{R_2^{1-\alpha}}. \tag{1.3.7}$$

Proposition 2. (Spatial Sorting) *Individuals with $\varphi \geq \varphi^{**}$ reside in City 2 and become team leaders. Those with φ such that $\varphi^* \leq \varphi < \varphi^{**}$ reside in City 1 and become team leaders. Workers consist of individuals with $\varphi < \varphi^*$ and reside in both cities.*

Proof. See Appendix A. □

The intuition behind this is that only the most skilled team leaders are able to pay the high housing price in City 2. Less skilled team leaders strictly prefer to be in City 1 because their income gain by locating to City 2 is not large enough to compensate the housing price difference. The property that more skilled individuals sort into cities where housing prices are higher and their rewards must be relatively higher is consistent with several key features of data documented in the literature (Wheeler, 2001; Glaeser and Resseger, 2010; Dahl, 2002). The lower panel of Figure 1.2 illustrates an example of sorting under the specified parameters.

The computation of the asymmetric equilibrium in which City 2 is more productive can be summarized as a fixed-point problem of S. The analytical computation, which is described in Appendix A, proceeds in two steps. First, given the spatial distribution of final goods, S, the system of an equilibrium is determined by two equations and two unknowns, φ^* and φ^{**}. All other variables are expressed as functions of these two productivity cutoffs and S. The second step is to pin down S using the comparative advantage condition, i.e., S must be the solution to equation (1.3.4).

The population of city j is endogenously determined through spatial sorting. Let $L_{E,j}$ denotes the number of team leaders in city j, then $L_{E,1} = L(F(\varphi^{**}) - F(\varphi^*))$, and $L_{E,2} = L(1 - F(\varphi^{**}))$. The total number of workers in both cities is $L_W = F(\varphi^*)$. Population in city j can be written as

$$L_j = L_{E,j} + \lambda_j L_W,$$

where λ_j denotes the share of workers in city j. Here, $L_{E,j}$ and L_W are functions of the two productivity cutoffs. In addition, λ_j is also endogenously determined and is a function of S. Appendix A gives the detailed computation of population L_j. It turns out that $L_1 < L_2$, as expected. The more productive city is larger in terms of size. In the numerical example described in the next section, City 2 has a larger number of both team leaders and workers.

The intuitive mechanism in the model is summarized as follows: suppose that City 2 has a larger set of skill-intensive components. City 2 is thus more productive and has a higher wage rate. The free mobility of workers results in City 2 having a higher housing price. This induces the sorting of team leaders. Only the most skilled team leaders will locate in City 2 because of the higher housing price. Lower skilled team leaders are better off in City 1. This sorting reinforces the equilibrium outcomes of the heterogeneity between cities. City 2 is more productive, has a higher housing price, and has comparative advantage of final goods that rely more heavily on skill-intensive components.

Recall that I began the analysis by assuming that City 2 has more skill-intensive varieties of components. By assuming that City 1 has more skill-intensive varieties of components instead, I can obtain another equilibrium, which is the mirror-image of the above equilibrium, where the positions of the two cities are reversed.

The fact that sorting leads to higher productivity and higher housing prices is exactly what the empirical literature finds (Diamond, 2013). In this model, I do not have perfect sorting. Workers locate in both cities, while only team leaders sort. This is consistent with empirical findings, as cities that are more productive overall also contain lots of workers with low productivity (Combes, Duranton, Gobillon, Puga, and Roux, 2012; Combes, Duranton, Gobillon, and Roux, 2012).

A Numerical Example

The numerical results show that an asymmetric equilibrium is unique in the sense that there is only one interior sorting equilibrium. Table 1.1 gives the specified parameter values, and the source of how these parameters are chosen.

Motivated by the findings of Behrens, Duranton, and Robert-Nicoud (2014), I use their estimated value of $\varepsilon = 0.05$, which is within the usual range in the literature.[5]

[5] See Glaeser and Resseger (2010), and Rosenthal and Strange (2004).

Table 1.1: Parameter Values

Parameter	Value	Source
ε	0.05	Behrens et al. (2014)
α	0.76	Davis and Ortalo-Magne (2011)
$\underline{\varphi}$	1	Basic Pareto distribution
δ	1	Behrens et al. (2014)
Y	1	Normalized to 1
L	1	Normalized to 1

The expenditure share α of final goods is set to 0.76, as Davis and Ortalo-Magne (2011) find that housing expenditure is on average constant across different cities, and they estimated expenditure share on housing is 0.24. The lower bound $\underline{\varphi}$ of the productivity distribution is set to 1, as in the basic Pareto distribution. The shape parameter of the Pareto distribution, δ, is also set to 1. As in Behrens, Duranton, and Robert-Nicoud (2014), the distribution of city sizes is endogenous to the sorting of heterogeneous individuals in a static spatial equilibrium, and if productivity follows a Pareto distribution, the size distribution of cities is also Pareto. The economy-wide income excluding land rents, Y, is normalized to 1. The mass of individuals in the economy, L, is also normalized to 1. The share of skill-intensive components in the final goods production, $\gamma(s)$, is assumed equal to s for all $s \in [0,1]$.

The solution of the asymmetric equilibrium is summarized by Figures 1.1 and 1.2. Figure 1.1 shows that the relative cost of production, $C_1(s)/C_2(s)$, is monotonically increasing in s. There actually exists a threshold S such that City 1 specializes in producing more labor-intensive goods in [0,S) while City 2 specializes in more skill-intensive goods in (S,1]. Here $S = 0.3319$ implies that $\Gamma_1 < \Gamma_2$. That is, City 2 has a larger market size of skill-intensive components. In other words, City 2 has a greater demand for goods that rely more on skill-intensive components. Thus, $Y_2 = \alpha Y(1-S) > \alpha YS = Y_1$, size of City 2 is larger in terms of income.

The upper panel of Figure 1.2 illustrates the occupational choice of individuals. As already noted before, wage rate w is flat since workers are equally productive and their income does not depend on their productivity φ. Team leader's income $\pi_j(\varphi)$ is monotonically increasing in φ. The productivity cutoff between team leaders and workers in City 1, φ_1^*, is where the curve $\pi_1(\varphi)$ intersects with wage rate w_1, as shown

Figure 1.1: Comparative Advantage and Pattern of Specialization in the Two-City World

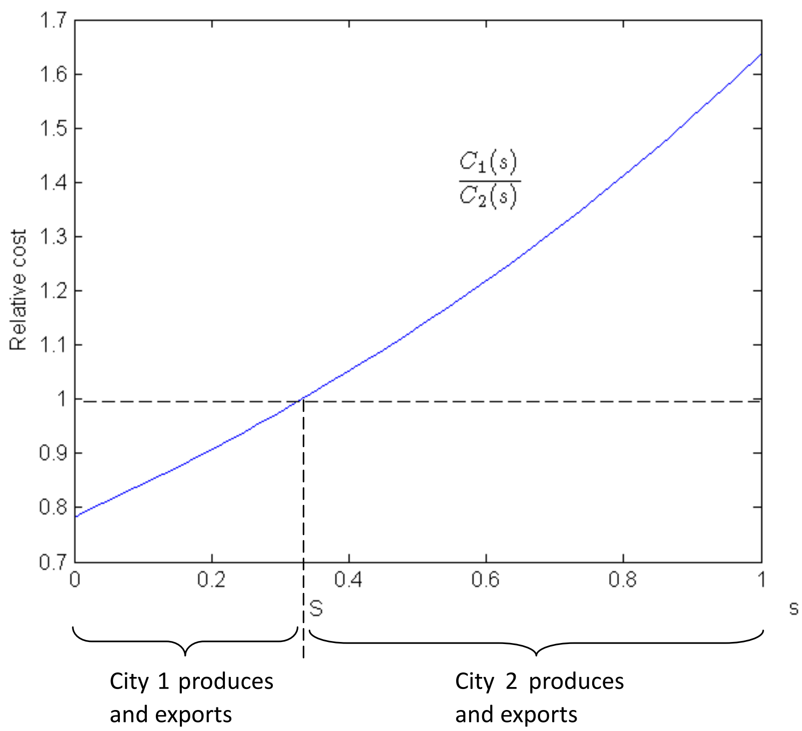
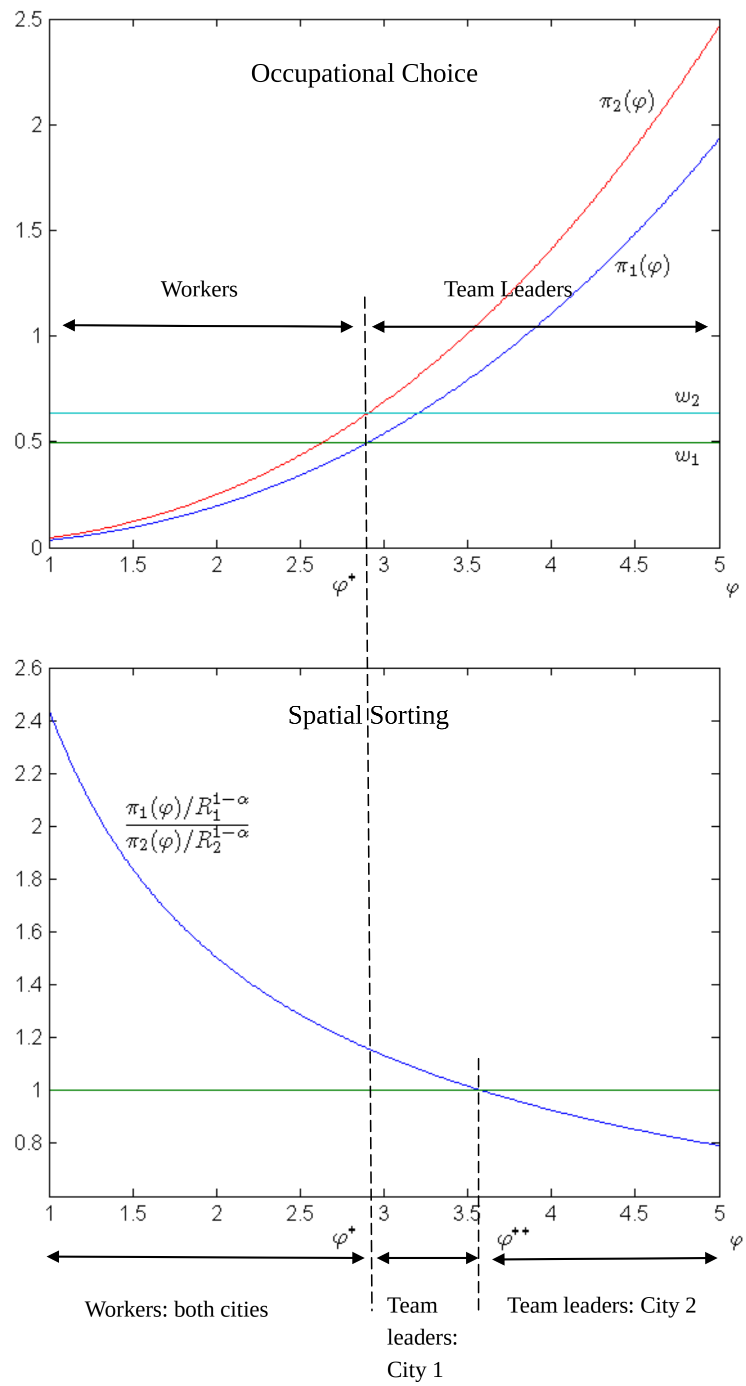


Figure 1.2: Occupational Choice and Spatial Sorting in an Asymmetric Equilibrium



in the figure. As in Lemma 1, higher w in City 2 leads to a proportionally higher $\pi(\varphi)$ in City 2. The threshold at which the two curves meet does not change.

The lower panel of Figure 1.2 gives the spatial sorting of individuals. The first productivity cutoff φ^* comes from the occupational choice given by the upper panel of Figure 1.2. Individuals with φ lower than this φ^* are workers, and since they are equally productive in both cities, they are indifferent to which city they reside in. The second productivity cutoff comes from the condition that a team leader with productivity φ^{**} is indifferent to which city she resides in,

$$\frac{v_1(P, R_1, y_1)}{v_2(P, R_2, y_2)} = \frac{\pi_1(\varphi)/R_1^{1-\alpha}}{\pi_2(\varphi)/R_2^{1-\alpha}},$$

and this ratio of indirect utilities equals to 1 at φ^{**}. As shown in the lower panel of Figure 1.2, the ratio of utilities conditional on choosing to become a team leader is monotonically decreasing in φ. In other words, with a low productivity, a team leader gets a higher utility by locating in City 1. But as her productivity increases, she is better off by moving to City 2. The threshold at which she is indifferent is where this curve achieves a value of 1.

1.4 Multi-City Equilibria

Now suppose there are J cities, $J \in \mathbb{Z}^+$. Note first that the same logic behind the instability of the symmetric equilibrium in the two-city economy implies that no two cities have the same set of skill-intensive varieties in any stable equilibrium. Without loss of generality, cities can be thus ranked in such a way that the measure of the set of varieties, $\{\Omega_j\}_{j=1}^J$, is monotonically increasing in j.[6] I start with the equilibria without this strict ranking of cities, however, to illustrate why such equilibria are unstable.

1.4.1 Unstable Equilibria without Strict Ranking of Cities

There are equilibria in which some cities have the same set of skill-intensive varieties. Without strict ranking, $\{\Omega_j\}_{j=1}^J$ is merely non-decreasing in j. The logic of symmetric

[6] Thus, the subscript j indicates the position of a city in a particular equilibrium, not the identity of the city.

equilibrium in the two-city economy carries over to the case of $J > 2$. Suppose for some j, $\Phi_j = \Phi_{j+1}$, i.e., there are two cities that have the same number of team leaders and all skill types are equally represented. Then it implies that for some j,

$$\frac{C_j(s)}{C_{j+1}(s)} = \frac{w_j}{w_{j+1}} = 1,$$

$\forall s \in [0,1]$. These two cities have the same cost of producing each good s. For a positive measure of goods, the consumers would be indifferent between buying from jth or $(j+1)$th city. Thus it implies the same argument as in the case of $J = 2$ that this class of equilibria is unstable.

1.4.2 Stable Multi-City Equilibrium

The stability of equilibrium requires that no two cities share the same set of endogenous variable, Ω_j. Cities can be ranked such that $\{\Omega_j\}_{j=1}^{J}$ is strictly increasing in j.

Comparative Advantage

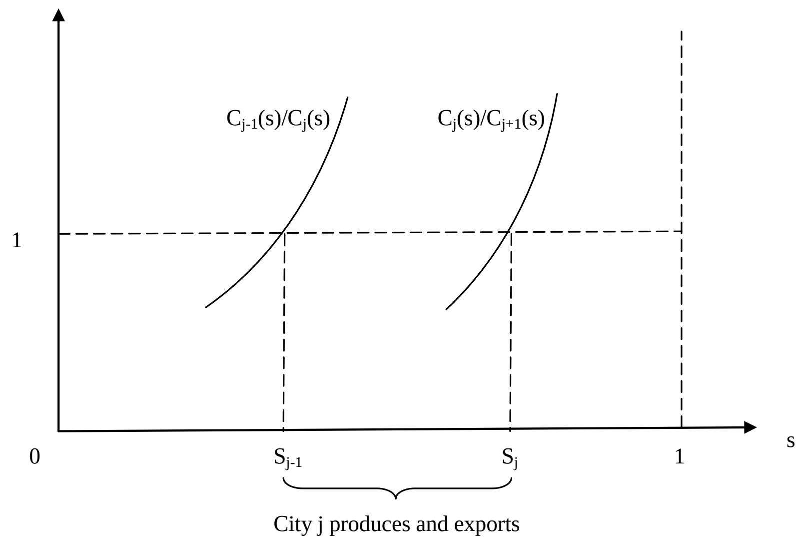
From (1.2.11), the relative cost of producing good s between the jth and the $(j+1)$th cities can be written as

$$\frac{C_j(s)}{C_{j+1}(s)} = \left(\frac{w_j}{w_{j+1}}\right)\left(\frac{\Phi_j}{\Phi_{j+1}}\right)^{-\gamma(s)},$$

which is increasing in s for any $j = 1, 2, ..., J-1$. In other words, a city with more or better team leaders (a larger Φ) has comparative advantage in higher-indexed goods, which rely more heavily on skill-intensive components. Wage rates $\{w_j\}_{j=1}^{J}$ also adjust in equilibrium so that each city becomes the lowest cost producer of a positive measure of goods. This implies that there is a sequence $\{S_j\}_{j=1}^{J-1}$, which can summarize the specialization pattern of final goods. The sequence $\{S_j\}_{j=1}^{J-1}$ is defined by

$$\frac{C_j(S_j)}{C_{j+1}(S_j)} = \left(\frac{w_j}{w_{j+1}}\right)\left(\frac{\Phi_j}{\Phi_{j+1}}\right)^{-\gamma(S_j)} = 1, \qquad j = 1, 2, ..., J-1,$$

Figure 1.3: Comparative Advantage and Patterns of Specialization in the Multiple-City World



which is increasing in j. It implies that the borderline sector, S_j, could be produced and exported by either jth or $(j+1)$th city because the cost of producing the good S_j is the same in both cities.

As shown in Figure 1.3, the final tradable goods are partitioned into J subintervals of positive measure such that the city j becomes the lowest cost producer of $s \in (S_{j-1}, S_j)$. The equilibrium wages can be written as

$$\frac{w_j}{w_{j+1}} = \left(\frac{\Phi_j}{\Phi_{j+1}}\right)^{\gamma(S_j)} < 1 \qquad j = 1, 2, ..., J-1.$$

Therefore, the wage sequence, $\{w_j\}_{j=1}^{J}$ is also increasing in j. That is, more productive city has a higher wage rate.

Individual Behavior

With $J > 2$ cities, there is a population of workers located in each city. In equilibrium, housing prices adjust to make each worker indifferent between locating in any of these

J cities:

$$\frac{w_j}{w_{j+1}} = \left(\frac{R_j}{R_{j+1}}\right)^{1-\alpha}.$$

Therefore, housing price sequence $\{R_j\}_{j=1}^{J}$ is also increasing in j, i.e., more productive cities have higher housing prices. The following Lemma 3 is the multiple-city version of Lemma 1.

Lemma 3. (Occupational Choice) *In any stable equilibrium with strict ranking of cities, the productivity cutoff for being a team leader is the same across all cities. That is,* $\varphi_j^* = \varphi_{j+1}^* = \varphi^*$, *for* $j = 1, 2, ..., J-1$.

The intuition behind this result is the same as in the two-city case. A city with a higher w_j has a proportionally higher $\pi_j(\varphi)$, due to the Dixit-Stiglitz demand of skill-intensive components and CRS at the level of producing each variety. The cutoff φ^*, which equates w_j and $\pi_j(\varphi)$, does not depend on j.

Lemma 4. *A team leader with productivity* φ *can always get higher income by locating to the more productive city. That is, for all* φ, $\pi_{j+1}(\varphi) > \pi_j(\varphi)$, *for* $j = 1, 2, ..., J-1$.

This means that given her productivity φ, a team leader can get the highest income if she locates in the Jth city. In equilibrium, however, not all team leaders locate there, because the Jth city also has the highest housing price. Therefore, there exists a sequence, $\left\{\varphi_j^{**}\right\}_{j=1}^{J-1}$ such that $\varphi_j^{**} > \varphi^*$ $\forall j = 1, 2, ..., J-1$ and team leaders with φ_j^{**} are indifferent between residing in jth and $(j+1)$th city. The cutoff $\left\{\varphi_j^{**}\right\}_{j=1}^{J-1}$ is defined as

$$\frac{\pi_j\left(\varphi_j^{**}\right)}{R_j^{1-\alpha}} = \frac{\pi_{j+1}\left(\varphi_j^{**}\right)}{R_{j+1}^{1-\alpha}}, \qquad j = 1, 2, ..., J-1.$$

Proposition 3. *In any stable equilibrium with strict ranking of cities, the hetereogeneous individuals are partitioned into* $J+1$ *intervals. Individuals with* $\varphi < \varphi^*$ *become workers and reside in every city. All individuals with* $\varphi > \varphi^*$ *become team leaders. (1) Team leaders with* φ *such that* $\varphi^* < \varphi < \varphi_1^{**}$ *reside in the 1st city. (2) Team leaders with* φ *such that* $\varphi_j^{**} < \varphi < \varphi_{j+1}^{**}$ *reside in the* $(j+1)$*th city. (3) And team leaders with* φ *such that* $\varphi > \varphi_J^{**}$ *reside in the* J*th city.*

1.5 Two Extensions

I extend the two-city model to analyze two types of local policies. The first extension of the model is to incorporate land use regulations. In particular, the assumption that the supply of housing is fixed at 1 is relaxed. This constraint of housing supply limits the ability of less skilled team leaders to access the high productivity available in City 2 because of the high housing price. The effect of stringent land use regulations on local housing prices is well documented in the literature (Glaeser, Gyourko, and Saks, 2005, 2006; Glaeser and Gyourko, 2005; Saiz, 2010). The inelasticity of housing supply not only is responsible for the higher housing price in City 2, but also affects how City 2 responds to increases in productivity. Positive perturbations on productivity in City 2 (which result in $\Phi_1 < \Phi_2$), have little impact on the expansion of new construction or the urban population. The fact that land regulations limit the growth of cities has been studied extensively in the literature (Hsieh and Moretti, 2014; Glaeser and Gottlieb, 2008).

The second extension of the model is to introduce local financial incentives. To reduce spatial disparities, local governments offer financial incentives to attract firms to less productive areas. Kline and Moretti (2013) report that an estimated 95 billion dollars are spent annually in the United States to attract firms to certain locations. Incentives come in many forms: cash grants and loans, sales tax breaks, income tax credits and exemptions, free services, and property tax abatements (Story, 2012). All of these aim at attracting the most productive firms, and thus the highly skilled workers to particular regions. These local financial incentives are widespread and have been studied in the literature (Busso, Gregory, and Kline, 2013; Mayer, Mayneris, and Py, 2012; Gaubert, 2014). This section will analyze the equilibrium effects of a local subsidy to City 1, the less productive city. It turns out that the policy has positive impact on the growth of the targeted city.

1.5.1 Land Regulations

In this section, I study the effects of land-use regulations. Following Saks (2008) and Glaeser, Gyourko, and Saks (2005), recent work argues that housing supply has become very inelastic in some places because of restrictive land-use regulations. Some land-use restrictions that are specifically targeted at multiunit dwellings can have national implications. A reasonable case that the extraordinary post-1990 growth of Atlanta, Dallas, Houston, and Phoenix, and the far more limited expansion of the regions around New York, Boston, and San Francisco, owes much to the differences in land-use regulations between these two sets of places (Glaeser and Tobio, 2008).

Model with a Housing Construction Sector

I start with the asymmetric equilibrium in the baseline model with two cities. Each city is still endowed with 1 unit of land, but I introduce a housing construction sector in City 1, the less productive city. Instead of letting competitive landowners convert each unit of land to one unit of housing, landowners construct housing h_j by combining their land θ_j with local labor $l_{H,j}$, according to the housing production function

$$h_j = \theta_j^{b_j} \left(\frac{l_{H,j}}{1 - b_j} \right)^{1-b_j}.$$

The land-use intensity parameter b_j restricts the amount of housing that can be built with a given amount of land. The lower the b, the more elastic the housing supply, given a fixed amount of land. Housing supply is perfectly inelastic when $b_j = 1$, which corresponds to the case in the baseline model. In the policy experiment, I analyze the case in which $b_2 = 1$ and how lowering b_1 impacts the economy.

The housing market in each city is competitive, and landowners take both the housing price R_j and the wage rate w_j as given. Since each city has 1 unit of land, the housing supply in each city can be written as

$$h_j^S = \left(\frac{R_j}{w_j} \right)^{\frac{1-b_j}{b_j}}.$$

Each individual consumes final goods and housing to maximize her utility (1.2.13). The demand for housing in each city is

$$h_j^D = \frac{(1-\alpha)\, Y_j}{R_j},$$

where Y_j is city j's income.[7] The housing market clearing condition in each city pins down the housing price. By introducing the housing construction sector, there are now three sources of labor demand, the demand from the production of labor-intensive components, the demand from each team leader, and the demand from landowners to build housing. Appendix A details the equilibrium housing prices and labor hired in the housing markets, as well as the computation of wages and income.

Policy Experiment

I model the relaxation of land-use regulations by decreasing the parameter b_1, which increases the elasticity of housing supply in City 1, the less productive city. I compare the sorting outcome and industrial specialization of two economies: one with $b_1 = b_2 = 1$ (perfectly inelastic housing supply in both cities as in the baseline model) and the other one with $b_1 = 0.5$ and $b_2 = 1$ (more elastic housing supply in City 1).

The results can be seen in Figures 1.4 and 1.5. The equilibrium outcomes of the occupational choice and sorting behavior are illustrated in Figure 1.4. The productivity cutoff φ^* increases as a result of decreasing b_1. This is due to the extra demand for workers by the housing construction sector, which raises the wage rate for workers. Some least skilled team leaders now find that being a worker is more attractive. The effect of lowering b_1 on the second productivity cutoff, φ^{**} is also positive. By making City 1 a more attractive place to live, some team leaders in City 2, now would like to move to City 1. These team leaders are the least skilled ones in City 2, but upon migrating to City 1, they become the most skilled in City 1. As a result, City 1 becomes more productive and larger because of the influx of skilled team leaders, while City 2 becomes less productive and smaller due to the leaving of team leaders.[8]

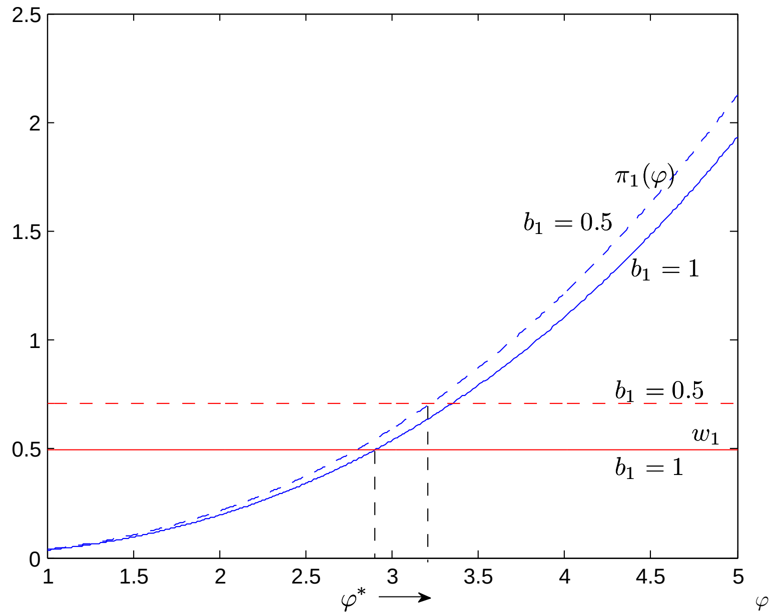
Figure 1.5 depicts the comparative advantage and pattern of specialization when b_1 is lowered. City 1 indeed becomes larger and more final goods sectors locate there. City 2 ends up having a smaller mass of final goods sectors, which produce the most skill-intensive goods. The equilibrium effects of the policy that increases the housing supply promote the growth of the city. City 1 will become larger as its housing supply

[7] Here I maintain the assumption of absentee landowners, i.e., the rents received by landowners are not included in Y_j.

[8] I define productivity at city level as aggregate productivity (in equation 1.2.8). One should note that the average productivity in both cities is higher as a result of an increase in φ^{**}.

Figure 1.4: Individual Behavior with Increased Housing Supply in City 1

(a) Occupational Choice



(b) Spatial Sorting

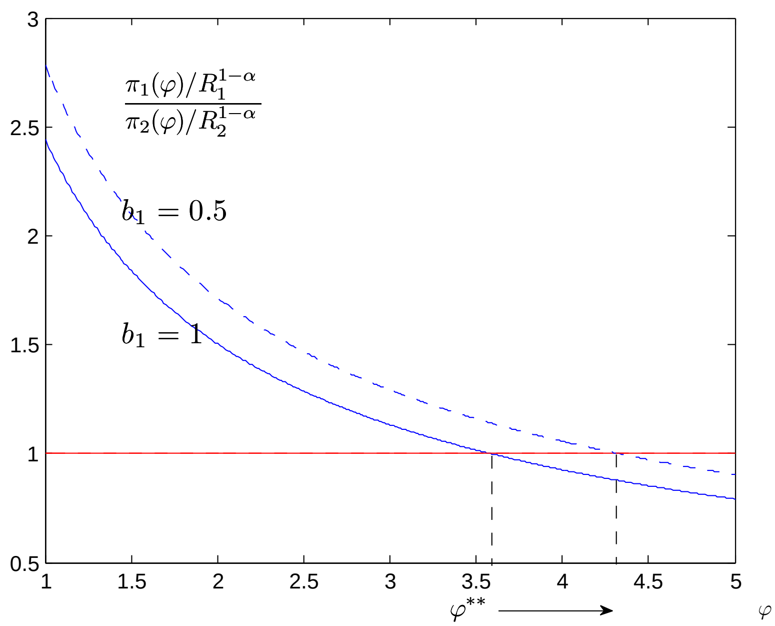
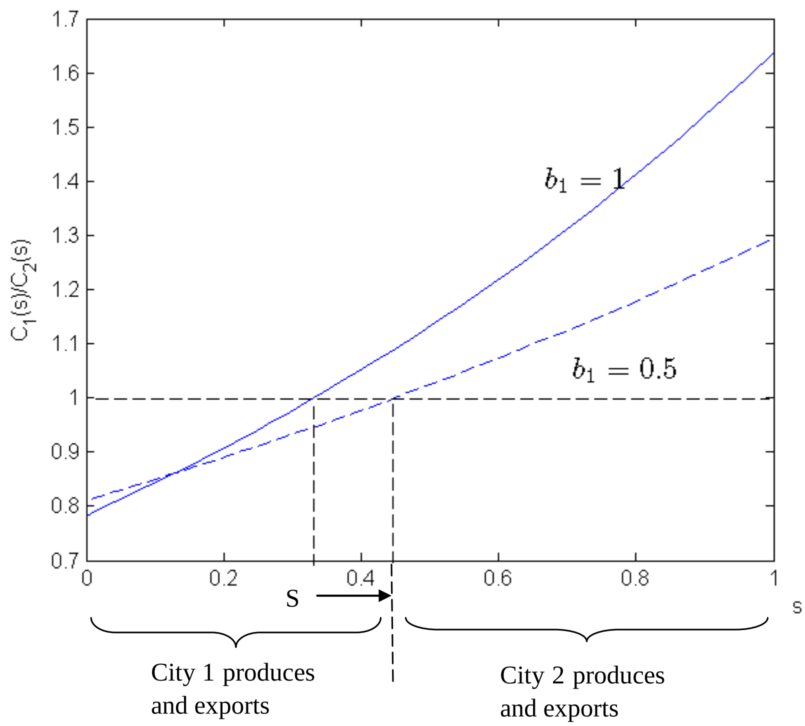


Figure 1.5: Pattern of Specialization with Increased Housing Supply in City 1



becomes more and more elastic. Least skilled goods previously produced in City 2 will be produced in City 1 and exported to City 2.

1.5.2 Local Financial Incentives

In this section, I examine the effects of a subsidy to team leader's income in City 1, as an analogue to subsidies or tax breaks offered to productive firms. This type of policies is widespread in the U.S. For example, Shell has been offered a tax credit worth as much as \$1.6 billion over 25 years from Pennsylvania, which competed with West Virginia and Ohio for an energy production facility; Caterpillar announced a new plant in Georgia, which offered \$44 million in incentives; San Francisco exempted Twitter from \$22 million in payroll taxes.

Model with a Local Subsidy

Formally, I start with my baseline model with two cities and introduce a local government in City 1, who fully tax local landowners and subsidize local team leaders. This is aimed at attracting more team leaders moving to City 1 to increase local productivity. The rate at which team leaders is subsidized, T_1, does not depend on team leader's individual productivity φ, since the government has little information over individual team leaders. Instead of (1.2.10), each team leader i who locates in City 1 gets

$$\pi_1(i) = (1+T_1)\frac{\varepsilon}{1+\varepsilon}\left(\frac{\varphi(i)}{\Phi_1}\right)^{\frac{1}{\varepsilon}} Y\Gamma_1.$$

The government finances the subsidy from the profits made on the housing market. The aggregate income of landowners in City 1 is

$$\pi_H = R_1 h - w_1 l_H = (1-\alpha)\, Y_1.$$

And the government balanced budget condition gives

$$(1-\alpha)\, Y_1 = L\int_{\varphi^*}^{\varphi^{**}} \frac{T_1}{1+T_1}\pi_1(\varphi)\, dF(\varphi),$$

which can be solved to obtain the equilibrium subsidy T_1^*. Appendix A provides the details of solving this equilibrium.

Policy Experiment

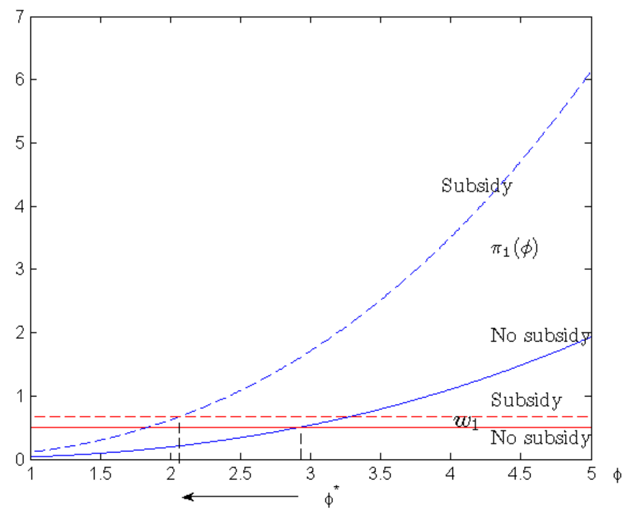
I model the implementation of this type of place-based policies by incorporating the subsidy T_1^* in City 1, while keeping City 2 unchanged from the baseline model, i.e., no subsidy in City 2. The equilibrium effects of such a policy are shown in Figures 1.6 and 1.7, in which I compare the results with those in the baseline model.

Figure 1.6(a) gives the change in the occupational choice as a result of the subsidy. The productivity cutoff for being a team leader, φ^*, decreases, as the subsidy in City 1 raises π_1 so that some workers now find it better off to be team leaders in City 1. Figure 1.6(b) depicts the change in the location choice. In fact, φ^{**} increases from 3.58 to 13.59. This is because the effect of the subsidy is large enough to induce a large number of team leaders to move from City 2 to City 1. The result is that City 1 is now larger, more productive, and has more skilled team leaders (more skill-intensive varieties of components).

The impact of the subsidy in City 1 is strong enough to reverse the equilibrium positions of the two cities, as illustrated by Figure 1.7. City 1 now has comparative advantage of higher-indexed goods, while City 2 has comparative advantage of lower-indexed goods. In this equilibrium with the subsidy, City 1 produces and exports skill-intensive goods in $(S', 1]$, and City 2 produces and exports labor-intensive goods in $[0, S')$. The large number of team leaders in City 1 increases local productivity, and City 1 surpasses City 2 and becomes the larger, more productive city in this economy.

Figure 1.6: Individual Behavior with a Subsidy in City 1

(a) Occupational Choice



(b) Spatial Sorting

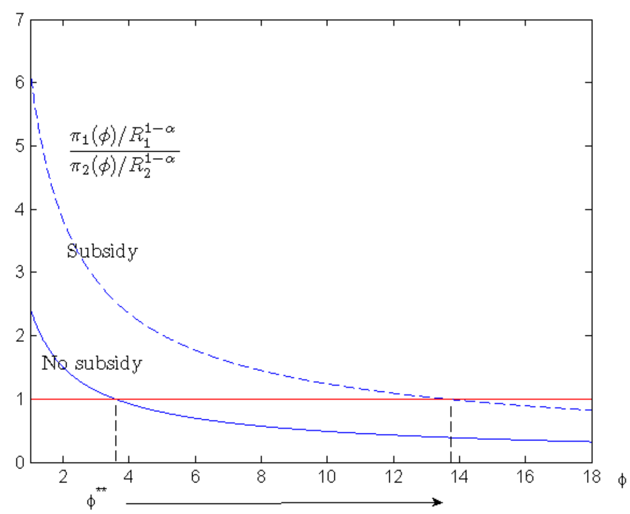
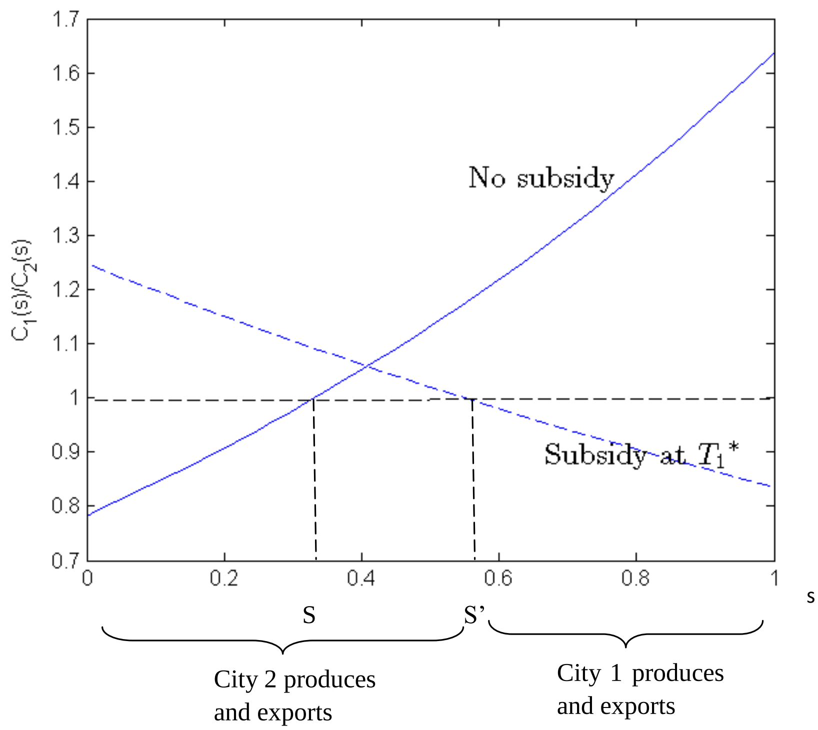


Figure 1.7: Pattern of Specialization with a Subsidy in City 1



1.6 Empirical Results

In this section, I empirically examine my predictions relating cities' housing prices to their sectoral distribution and skill distribution of workers. First, I study the pattern of industrial specialization across cities with different housing prices. To do this, I estimate the effect of housing prices on employment shares for each industry. Then I construct a skill-intensity index for each city and test whether expensive cities specialize in more skill-intensive industries. Second, I examine whether it is true that more highly skilled workers live in places where housing prices are high, as predicted in my model. Finally, I look at the effects of the two types of policies on the change in housing prices, income, and populations.

Data are broadly consistent with my model's predictions. More skill-intensive sectors locate in places with high housing prices. Skilled workers are more skilled in cities where housing prices are high. Moreover, both types of policies have positive local effects on the growth of cities.

1.6.1 The Spatial Distribution of Industries

This section examines the spatial pattern of economic activities. In my theory, more productive cities have higher housing prices and have comparative advantage in more skill-intensive goods. I now examine whether cities with high housing prices specialize in skill-intensive sectors.

Housing Prices and Sectoral Employment Shares

I define a city as a Metropolitan Statistical Area (MSA). Metropolitan area boundaries are based on their 2003 definitions, as issued by the Office of Management and Budget. Housing price data are taken from Carrillo, Early, and Olsen (2014).[9] Employment data are taken from the 2010 County Business Patterns published by the U.S. Census Bureau, which contains data for 6-digit NAICS industries across 348 MSAs. I focus on all three-digit manufacturing sectors. There are 21 such industries. For each industry, I calculate its employment share in each of these 348 metro areas. To test whether

[9] See Appendix A for details on data.

cities with high housing prices specialize in sectors that are skill intensive, I run a cross-section regression. For each industry, I regress the employment share on housing prices across cities. The coefficient from each regression gives the effect of a change in housing price on the change in employment share. A positive coefficient means that there is a larger share of that industry in cities with higher housing prices. In contrast, a negative coefficient indicates that the share of that industry is smaller in expensive cities.

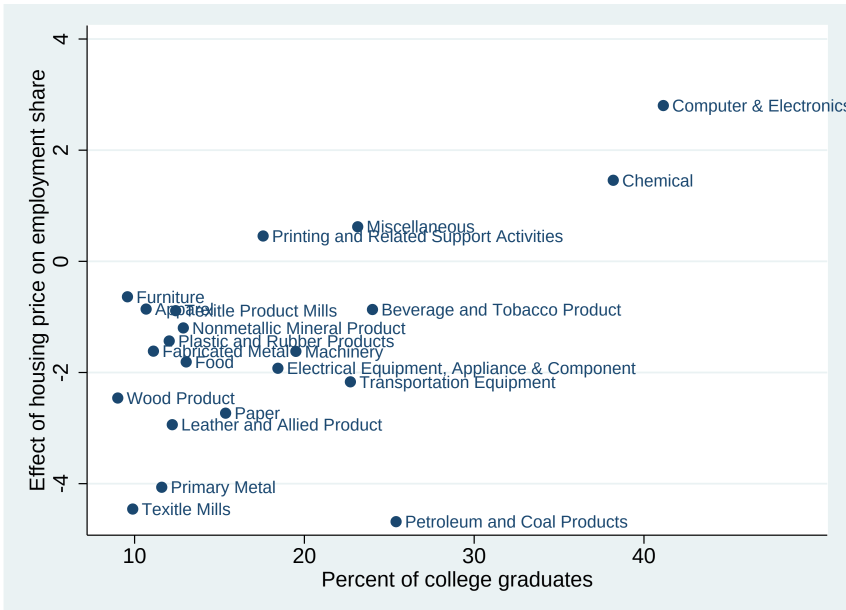
The regression results are shown in Table A.1 in Appendix A. Figure 1.8 gives a visualization of the regression analysis. It plots the 21 industries' estimated coefficients against their skill intensities, measured as the percent of college graduates in each industry.[10] There is a clear positive relationship.[11] More skill-intensive sectors have coefficients that are larger and positive, while less skill-intensive sectors have smaller and negative coefficients. In particular, computer and electronic products manufacturing has 41.14% of workers with a bachelor's degree and a 1% rise in housing price is associated with 2.8% rise in its employment share. On the other side, only 9.89% of employees in the textile mills sector are college graduates, and a 1% increase in housing price is associated with 4.46% decrease in its employment share. The pattern of specialization is clear here: cities with high housing prices specialize more in skill-intensive sectors than they do in less skill-intensive sectors. This is exactly what my model generates. In any stable equilibrium, cities organize themselves into specializing different sets of goods. The city which specializes in tradable goods that rely more heavily on skill-intensive components has a higher housing price in equilibrium.

The empirical literature on classifying cities based on their degrees of specialization is limited. Black and Henderson (2003) look at all two-digit SIC industries in 1992 and group cities into different clusters on the basis of similarities of production patterns, indicated by employment shares of different industries. They also look at the average size and percent of college graduates in each group. Another related paper is Davis and Dingel (2013). They calculate the elasticity of occupational and sectoral employment with respect to city sizes and find that skill-intensive industries have higher elasticities.

[10]See Appendix A for data sources and detailed description on how to calculate the skill composition in each industry.

[11]The only outlier is petroleum and coal product manufacturing, which depends heavily on natural resources in the particular region.

Figure 1.8: Industries' Skill Intensities and Housing Price Effects



Housing Prices and City-Specific Skill Intensities

The unit of analysis in the previous section is an industry. It only gives us information on the employment share of each industry across cities, not the industrial composition of each city. To correct for this, for each city I construct a skill-intensity index, SI, as follows,

$$SI_i = \sum_j \%college_j \times s_{ij}.$$

The skill-intensity index in city i is the sum of the percent of college graduates in each industry j times the employment share of industry j in city i, s_{ij}.[12] In other words, it is the weighted average of skill intensities across all industries in a city. I keep the index between 0 and 1. Thus, if a city has a skill-intensity index of 0.3, that means the average percent of college graduates working in manufacturing industries in this city is 30%. Here I study yearly data between 2003 and 2006, in order to adjust for city fixed effects.[13] Again I look at 21 three-digit manufacturing sectors in 348 Metropolitan

[12] The data on individuals' education and industries in which they are employed come from the American Community Survey made available by IPUMS-USA. See Appendix A for details on data.

[13] There are two reasons for selecting this time period. First, in 2003, the Office of Management

Figure 1.9: City-Specific Skill Intensities and Housing Prices, 2006

Statistical Areas. Figure 1.9 gives a simple cross-city plot of the skill-intensity index against housing price for the single year 2006, indicating a positive correlation between these two. Cities that have high housing prices have higher skill-intensity indices. These cities are skill abundant and specialize in skill-intensive sectors.

The regression results are reported in Table 1.2. The relationship between skill intensity and housing price is the main focus of this paper. Nonetheless, I also add population and per capita income as explanatory variables in the regression. The importance of population in theories of cities is vastly emphasized in the urban economics literature. Population has been used to analyze agglomeration economies in cities. It is a well known fact that larger cities (in terms of population) typically have a greater share of college graduates. Davis and Dingel (2013) find empirical evidence that larger cities specialize in skill-intensive sectors. Here I test if population affects the city-specific skill intensity. Per capita income is also included in the regression model. I expect cities

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and Budget (OMB) revised the definitions and codes of Metropolitan Statistical Areas. For example, some previous separate metro areas were combined to form a single metro area. More importantly, the codes that identify these metro areas were changed. Therefore, it is hard to consolidate and study the cross-city data before 2003 with data after 2003. Second, the housing bubble burst in the U.S. during the financial crisis in 2008. It is then unwise to study housing data on or after 2008.

with high income have relatively more skilled workers and thus have higher skill-intensity indices.

Table 1.2: Housing Prices and Skill Intensities in U.S. Cities

	Log skill-intensity index		
	(1)	(2)	(3)
Housing price	1.244***	1.061***	0.132
	(0.140)	(0.173)	(0.416)
Population		0.643	0.692
		(0.358)	(0.357)
Per capita income			0.689*
			(0.282)
City fixed effects	Yes	Yes	Yes
Observations	1392	1392	1392
Number of cities	348	348	348
Number of years	4	4	4
R-squared	0.695	0.696	0.699

Standard errors in parentheses
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

The effect of housing price on the skill-intensity index is very strong. Column (1) indicates that cities with 1% higher housing prices have, on average, 1.24% higher skill intensities. Even controlled for population, a 1% rise in housing price index leads to a 1.06% increase in skill-intensity index. The variable population is, however, not statistically significant in explaining the variation of skill intensities between cities, as shown in Column (2). The last regression with income is not informative, as the hypothesis that all regressors equal zero cannot be rejected.

There is a small literature on cross-city distribution of sectoral activities, but the results obtained from Table 1.2 are consistent with the literature. Holmes and Stevens (2004) survey the spatial distribution of economic activities in North America. They show that agriculture, mining, and manufacturing are disproportionately in smaller cities and finance, insurance, real estate, professional, and management activities are disproportionately in larger cities. While this paper does not focus on the effect of population size on spatial activities, the equilibrium outcome of the model indicates that cities that specialize in skill-intensive sectors are indeed larger.

1.6.2 The Spatial Distribution of Skills

While there is evidence that a meaningful share of spatial distribution of skills is attributable to spatial sorting of heterogeneous workers (Davis and Dingel, 2012; Eeckhout, Pinheiro, and Schmidheiny, 2014), this sorting is incomplete and individuals of many skill types are present in every city. My model yields this imperfect sorting, since there is sorting amongst team leaders but workers locate in both cities and are equally productive. Therefore, the model only predicts the upper tail of the skill distribution, not the lower tail. The main empirical finding in this section is that the distribution of skills in expensive cities has fat upper tail. In other words, cities that have high housing prices attract more highly skilled individuals. This is exactly what the theory predicts: the most skilled team leaders sort into cities with high housing prices and less skilled team leaders are better off in cities with lower housing prices.

The source of data is the Current Population Survey (CPS) for the year 2010. To test the upper-tail distribution of skills across cities, I restrict my sample to only include relatively skilled people, i.e., those with at least some college education. I group them by their educational attainment: some college (including associate degrees), bachelor's degrees, and master's and higher degrees. This educational classification has been used as a direct measure of skills before (recent examples include Eeckhout, Pinheiro, and Schmidheiny, 2014; Davis and Dingel, 2012). Figure 1.10 visualizes the fraction of skilled workers in these three educational groups in cities with high and low housing prices. It shows that cities with housing prices in the first quartile have more workers with some college education, but less workers with bachelor's or higher degrees, compared to cities with housing prices in the fourth quartile. Namely, skilled workers are more skilled in cities with high housing prices, thus confirming the theoretical prediction that more skilled team leaders sort into cities where housing prices are high.

1.6.3 Effects of Policies on Housing Prices, Wages, and Populations

This section examines the effects of the two types of policies, as described in Section 1.5. To do this, I conduct the following regression analysis:

$$y_i = \beta_0 + \beta_1 ln(x_i) + \beta_2 z_i + \beta_3 ln(x_i) z_i + \epsilon_i.$$

Figure 1.10: Skilled Are More Skilled in Expensive Cities

Here, y_i, which can be the housing price index, (log) income per capita, (log) population for each city i, is regressed on metropolitan-level characteristics that capture the two types of policies. The first predictor is x_i, the fraction of highly skilled among the group of skilled workers, measured by the ratio of those with bachelor's or higher degrees to all those who have at least some college education. Recent research documents that a larger amount of human capital in a city increases productivity (Glaeser and Saiz, 2004; Moretti, 2004a,b). This predictor reflects the policies that attract highly skilled workers to specific regions. These place-based policies will lead to an increase in x.

The extended model in Section 1.5.1 predicts that a more elastic housing supply in City 2 will have positive local effects on income and population, compared to the baseline model. Therefore, one key empirical test is to estimate the effect of land regulations. To do this, I include the second predictor, a dummy variable z_i, for highly regulated land markets. Data for this variable are taken from Gyourko, Saiz, and Summers (2008). They quantify the land-use regulations by creating the Wharton Residential Land Use Regulation Index. The index is scaled to have a mean of zero, a standard deviation of one, and is increasing in the amount of regulation.[14] Instead of treating regulation as a continuous variable, I use a dichotomous division of the Wharton Index ($z_i = 1$ for highly regulated cities). I define metropolitan areas with a value of the index greater than 0.34 to be locations with high regulations, which comprise the highest third of the cities in my sample. This is because 89 out of the 293 metro areas clustered around the mean.

Table 1.3: Effects of Policies on Housing Prices, Income, and Populations, 2010

	Housing price index	ln(Income/capita)	ln(Population)
Fraction of skilled	0.221**	0.198***	1.267***
	(0.081)	(0.051)	(0.346)
High regulation	0.358**	0.272***	-0.125
	(0.118)	(0.074)	(0.506)
Fraction of skilled × high regulation	0.090	0.275**	-0.254
	(0.143)	(0.089)	(0.610)
Observations	203	194	201
R-squared	0.334	0.355	0.284

Standard errors in parentheses
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

The results can be seen in Table 1.3. The coefficients in the second row capture the impacts of land regulations. More severe regulatory environment is associated with higher housing prices and income, but not the expansion of city size. The coefficient of 0.358 indicates that highly regulated cities have higher housing prices. This effect is equivalent to about three-quarter of a standard deviation of the housing price index, which is quite large. Highly regulated cities also have 0.272% higher per capita income. Finally, more severe land regulation is not associated with greater size of cities. The point estimate is negative, but it is not statistically significant. In sum, as predicted in the model, an inelastic housing supply makes the city affordable to only the most skilled people, thus increases average income and restricts the city becoming too large.

The coefficients in the first row reflect the impacts of the local financial incentives in the typical low-regulation metropolitan area, while those in the third row report the differential effects of these policies in an area with a highly regulated housing supply. A

[14]While the mean of the full sample is zero, the mean of metro areas is 0.14, reflecting higher land regulations in metro areas. There are 293 MSAs included in their sample.

larger fraction of highly skilled workers is associated with higher housing prices, income, and populations. This measure of place-based policies strongly predicts growth in low-regulation metropolitan areas. The extension in Section 1.5.2 builds on the baseline model, hence the coefficients in the third row, the impacts of the interaction between this variable and the degree of housing supply regulation, should be considered as well. The results indicate that more inelastically supplied housing markets have higher per capita income, but there is no differential impact found for housing prices and populations. These results are consistent with what the model predicts: local financial incentives attract more skilled workers to locate there, thus lead to a boom in the housing price, income, and population in the targeted area.

1.7 Conclusion

This paper proposes a theory of cities in which all cross-city heterogeneity is endogenous. A difference in productivity leads to a difference in worker's wage rates across cities. In equilibrium, the housing price in the more productive city is higher, due to the utility equalization of workers. This higher housing price induces sorting: only the most talented team leaders will locate there. Less skilled team leaders are better off in the less productive city. This sorting supports the equilibrium outcomes of the heterogeneity between cities. Cities with higher housing prices exhibit higher wages, productivity, aggregate income, populations, and skill intensities - all prominent features in the data. Extended to incorporating land regulations and local financial incentives, the model provides a foundation to study the equilibrium effects of these policies in a two-city scenario. Both types of policies lead to an increase in the productivity, income, and population in the targeted area.

A distinguishing feature of the model is that it explains spatially heterogeneous outcomes as emergent results of the sorting process, without relying on assumptions of asymmetries in individual's ability to move or cities' fundamental characteristics. Yet it yields a rich set of spatial patterns. I find empirical evidence from U.S. data for the pattern of industrial specialization and skill distribution. Analyzing at both industry and city level, I find that cities with higher housing prices specialize in more skill-intensive sectors. The skill level in the top percentiles of these cities is higher.

Given the theory, this provides empirical support for the spatial sorting of individuals and comparative advantage of cities: the comparative advantage in tradable sectors that depend more on skill-intensive components makes more skilled team leaders, who produce these components, locate there. In addition, the empirical results provide insights into the effects of policies on the targeted places. Using the Wharton Index as an approximation of the severity of housing regulation, I find that higher land regulations in cities can lead to a boom in housing prices and income. This supports the theory that if the housing supply is fixed, only the most skilled team leaders locate there, reinforcing the high housing price and income in the city. I also measure the skill level in the top percentiles of the skill distribution across cities by calculating the ratio of people with at least a bachelor's degree relative to those with some college education. The regression analysis provides empirical support for the model. More skilled workers in a city increase the local housing price, income, and population, thus the policies that attract highly skilled workers encourage the growth of cities.

Chapter 2

A Spatial Explanation for Cross-City Price Differences

2.1 Introduction

The variation in prices across cities plays an important role in many urban and New Economic Geography (NEG) models. The vast majority of literature emphasizes on the price of tradable goods and land price. Theories typically predict that price indices over tradable goods are lower in larger cities (see, e.g., Fujita (1988); Krugman (1991); Helpman (1998); Behrens and Robert-Nicoud (2014)). This prediction is at odds with some empirical work (DuMond, Hirsch, and Macpherson (1999); Tabuchi (2001)), but it is easy to modify NEG models to generate higher housing prices in larger cities. However, there are limited studies on the cross-city price differences of non-tradable goods other than land. This paper provides an empirical analysis to document this fact and a theoretical explanation for it.

The contribution of this paper is two folds. First, the paper documents the key observations on price differences. Large cities have higher aggregate price indices. Contrary to existing theories, prices of tradable goods are higher in larger cities. Prices of non-tradable goods (except land or housing) also rise with population. Though all three price indices increase with population, the price difference is larger in non-tradable goods but smaller for tradable goods. Second, the paper provides a spatial model that explains why relative price of non-tradable goods is higher in cities with higher population. The model features an internal spatial structure of cities: locations within cities are heterogeneous and more desirable locations are occupied by agents who can gain more out of it. In equilibrium, all agents choose their optimal location. The model provides a microeconomic foundation for the stylized facts on cross-city price differences.

More specifically, I use a monocentric city model in which market exchange takes place at the city center. I study a circular city with a central business district (CBD) surrounded by a ring of residences. Two goods, tradable manufacturing goods and nontradable service goods, are produced using land and labor, while people consume these two types of goods and residential land. Firms incur iceberg transport costs and the transport costs differ across sectors. Services generally need face-to-face meeting, hence it is most expensive to deliver service goods. Commuting, on the other hand, takes the form of a loss of labor time and is the cheapest of all transportation activities. The need to save on transport costs draws both firms and residents towards the city center, while the need for land in production and residential housing keeps the city from collapsing on a point.

In equilibrium, all agents choose their optimal location. Firms, by locating closer to the city center, save transport costs but face a higher land price and wage rate. Since service sector has the highest transport cost, it has more to gain from being closest to the center, followed by the manufacturing sector. Consumers also have a trade-off: by locating closer to the CBD, commuting cost is lower but land price is higher. Workers are free to move across sectors so they are indifferent between working at different locations within CBD. Every consumer-worker at every location receives the same utility, i.e., no one can gain by changing her residential or job location. The equilibrium land use gives three boundaries regarding the internal structure of the city: a boundary between service and manufacturing sector within CBD, a boundary between CBD and residential area, and a boundary between urban residential area and rural land use, namely, the city edge.

The equilibrium analysis is in terms of a closed city: the city's population is taken as given and the equilibrium determines the city's geographic size and the utility it can deliver to its residents. In particular, I establish the equilibrium relation between city's population, the three boundaries, and relative price of service goods. As population grows, the city edge increases. This is because residents demand more goods as well as land, and firms also need more land for production in order to meet the increased demand. This increase in city edge pulls out both internal boundaries within the city that divide the land to different use. In particular, as the boundary between service and manufacturing sector increases, service sector is affected proportionately more, because service sector has a higher transport cost. Therefore, service goods become relatively more expensive.

Empirically, I document the facts about the price differences across cities. Using the detailed component data on 56 individual goods and services collected in 209 U.S. cities in 2010, I construct price indices for tradable and nontradable goods for each city. I find that aggregate city-level Consumer Price Index, tradable and non-tradable price indices all increase with population. In particular, a one log-unit rise in city size is associated with a 3.4% increase in non-tradable price index but only a 1.2% increase in tradable price index. This is consistent with other empirical studies. Cecchetti, Mark, and Sonora (2002) study the aggregate price levels among cities. They find significant price differences across cities and very slow convergence. Parsley and Wei (1996) and Engel and Rogers (1997) both examine violations of the law of one price within the United States using consumer price data. In particular, Parsley and Wei (1996) examine prices for different categories of goods. They classify goods into tradables and non-tradables, and within the tradable category they make a further distinction between perishable goods (mostly vegetables and dairy products) and nonperishable goods. They find that services have the highest average price differential.

A distinguishing aspect of the model is that it features an explicit internal structure of cities to demonstrate the relation between city's population and prices, which has not been studied before. The most closely related paper is Karadi and Koren (2008), who develop a spatial model to explain why price level is higher in rich countries. My paper is different in two main aspects. First, their model is used to explain the Balassa-Samuelson effect between countries, while my model explains the cross-city price differences within a country. Second, their paper's spatial structure takes a different form. They model each country as an interval on the real line. Furthermore, residents are assumed to live in the center and business locates father away from the center. In contrast, I describe a circular city in a monocentric city model, whereby a central business district is surrounded by a ring of residences, as developed in classic work by Alonso, Mills, and Muth in the late 1960s. Another closely related paper is Chatterjee and Eyigungor (2013), which builds on Lucas and Rossi-Hansberg (2002). Their paper focuses on the role of externalities on land price in cities with different supply restrictions.

The paper is related to several strands of the literature. The model builds on and expands the large theoretical literature on monocentric city model (See Fujita (1989); Fujita and Thisse (2013); Fujita, Krugman, and Venables (1999); and Anas, Arnott, and Small (1998) for a review). It extends traditional models in that it has a spatial division within the central business district (CBD), i.e., the service production zone and the manufacturing production zone. This paper also complements the empirical literature that studies cross-city price differences. Crucini and Shintani (2008) use similar data as the current paper to examine the persistence of law of one price deviations for nine U.S. cities. Atkin and Donaldson (2014) estimate intranational trade costs by using spatial price index as a proxy. Handbury and Weinstein (2014) use detailed barcode data to identify sources of bias in spatial price index measurement. In complementary work, Handbury (2013) uses the same barcode data to calculate variety-adjusted city-specific price indices for households at different income levels. The barcode data, however, only cover food items.

In what follows, Section 2.2 presents detailed empirical facts about the cross-city price differences of both tradable and non-tradable goods. Section 2.3 introduces a spatial model with an internal structure of cities. Section 2.4 derives the equilibrium conditions and conducts analysis on why relative price of service goods is higher in larger cities. Finally, Section 2.5 concludes.

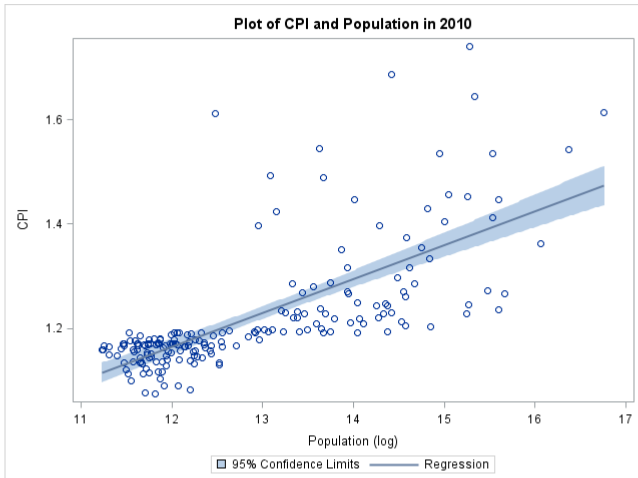
2.2 Data

The data is taken from ACCRA (American Chamber of Commerce Researchers Association) Cost of Living Index published by the Council for Community and Economic Research. The ACCRA index of U.S. urban prices has been used in important papers such as Chevalier (1995), Parsley and Wei (1996), Albouy (2009), and Moretti (2013). It provides comparative data for 318 urban areas. Items on which the Index is based have been chosen to reflect the different categories of consumer expenditures. ACCRA data are weighted according to the Consumer Expenditure Survey by U.S. Bureau of Labor Statistics. The ACCRA Cost of Living Index measures relative price levels for consumer goods and services in participating areas. The average for all participating places, both metropolitan and nonmetropolitan, equals 100, and each participant's index is read as a percentage of the average for all places. Because each ACCRA report is a separate comparison of prices at a single point in time, I use the 2010 annual average data to study the price differences across cities. I define a city as a Metropolitan Statistical Area (MSA). Metropolitan area boundaries are based on their 2003 definitions, as issued by the Office of Management and Budget. Based on this definition of cities, the dataset is reduced to 209 cities in the U.S.

The main advantage of this dataset is that it contains detailed components data for 56 individual goods and services. The main categories of goods and services in the data are: grocery items, including meats, dairy products, produce, bakery products, and miscellaneous grocery products such as sugar and soft drinks; housing, measured as monthly rent for a two-bedroom apartment and monthly payment for mortgage; utilities, including total home energy cost and telephone; transportation, such as auto maintenance; health care, including office visits for doctor or dentist, and medicine such as ibuprofen; and miscellaneous goods and services, such as pizza, haircut, movie, etc. I group these 56 individual goods and services into two types: tradable and non-tradable goods. Tradable goods include all the grocery items, miscellaneous goods such as toothpaste, shampoo, medicine, clothing items, sports items, and liquor. Non-tradable goods (except land/housing) include utilities, transportation, healthcare services, miscellaneous goods and services such as prepared food in restaurants, beauty services, repairs and dry cleaning.

The variation in prices across locations is a central issue to economic geography and international economics. The correlation of price indices with population, which yields a common agglomerating force across many New Economic Geography (NEG) models, is the main focus of this section. Figure 2.1 shows the correlation between aggregate price index (the composite index) and population. Clearly, price rises with population. To see if price indices for tradable and non-tradable goods also rise with population, I construct tradable price index (P_T) and non-tradable price index (P_N) from the ACCRA

Figure 2.1: Correlation between City-Level CPI and Population, 2010



dataset, using the ACCRA item-level weights.

I regress the log of each price index for each city on the log of the city's population and report the results in Table 2.1. As shown in the table, there is a strong positive association between each of these price indices and population. Although the composite ACCRA index, which includes land prices, rises the steepest with population, there is a very similar pattern for both the tradable and non-tradable price indices. A one log-unit rise in city size is associated with a 3.4% increase in non-tradable price index but only a 1.2% increase in tradable price index. These coefficients are economically significant as well. It indicates that a consumer in New York pays 4 percent more for tradable items but 12 percent more for non-tradable items than a person in Des Moines. The large price difference between the non-tradable goods needs further investigation into the theory.

NEG models typically predict that price indices over tradable goods are lower in larger cities (see, e.g., Fujita (1988); Rivera-Batiz (1988); Krugman (1991); Helpman (1998); Ottaviano, Tabuchi, and Thisse (2002); Behrens and Robert-Nicoud (2014)). This prediction is at odds with the empirical analysis above. Other empirical work also has demonstrated that prices are higher in larger cities (DuMond, Hirsch, and Macpherson (1999); Tabuchi (2001)). Helpman (1998) and Suedekum (2006) suggest that, while the price of purely traded goods should be lower in cities, the inclusion

Table 2.1: Price Indices and Population, 2010

	(1) log P_T	(2) log P_N
log MSA Population	0.0122***	0.0338***
	(0.00361)	(0.00747)
Constant	4.445***	4.157***
	(0.0469)	(0.0971)
Observations	209	209
Adjusted R^2	0.31	0.35

Standard errors in parentheses

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

of non-tradable prices in the aggregate price index can produce an inconclusive result. However, my empirical analysis in this section shows that larger cities do have higher price, in all three price indices, and the price difference is larger for non-tradable goods but smaller for tradable goods. Contrary to theories in New Economic Geography literature, both tradable and non-tradable prices rise with population. This illustrates the importance of relative price of non-tradables in developing the theory in this paper.

2.3 Model

Space is modeled as a flat and featureless plain, with an arbitrary point marked off as the center. I study a circular city with radius S in the plain, considering only symmetric allocations. Therefore, a location is fully described by the location's distance r from the city center $(0, 0)$. The city center serves as a marketplace: all goods and services are exchanged there. Land is owned by agents who play no role in the theory: absentee landlords.

Production Technology

There are two goods: manufactured goods, which is the numeraire, and services. Both are costly to transport to the center. Let $n_i(r)$ be the employment by industry i $(i = m, s)$ per unit of land at location r. Production at location r is assumed to be a constant returns to scale function of land, $2\pi r$, and labor, $2\pi r n_i(r)$, at that location.

Production in each industry i per unit of land at location r is

$$Y_i(r) = A_i n_i(r)^{\beta}, \qquad \beta \in (0,1),$$

where A_i is a TFP term that is common to all firms in industry i in the city. Firms incur an iceberg transport cost: when one unit of good is shipped r miles, only $exp(-\tau_i r)$ remains.

Let $w\left(r\right)$ be the market wage at location r. Let $q_F^i(r)$ be the maximum rent a firm would be willing to pay for a unit of land at location r. Firm's problem implies that $q_F^i\left(r\right)$ is the maximized profit a firm can get per unit of land,

$$\begin{aligned} q_F^i(r) &= p_i exp(-\tau_i r) A_i n_i(r)^{\beta} - w(r) n_i(r) \\ &= \max_{\{n\}} \left\{ p_i exp(-\tau_i r) A_i n_i^{\beta} - w(r) n_i \right\}. \end{aligned} \tag{2.3.1}$$

Consumers

Each consumer is endowed with one unit of labor, which she supplies inelastically to the joint activity of working and commuting. There is a technology for commuting. Following Anas, Arnott, and Small (2000) and Lucas and Rossi-Hansberg (2002), the commuting cost takes the form of a loss of labor time that depends on the distance travelled to and from work. Specifically, I assume that a worker who resides in location r and commute to a firm at location t has $exp(-\kappa|t-r|)$ unit of time to devote to production, where $\kappa > 0$. Symmetric allocations imply that a worker only commutes along the straight line that connects her residential location and the city center. There is no commuting cost for shopping, as shopping can be viewed as a leisure. Consumer's preference can be written as

$$u(m,s,l) = m(r)^{\alpha_1} s(r)^{\alpha_2} l(r)^{\alpha_3},$$

where $\alpha_1, \alpha_2, \alpha_3 \in (0,1)$ and $\alpha_1 + \alpha_2 + \alpha_3 = 1$. Here $m\left(r\right)$, $s\left(r\right)$, and $l\left(r\right)$ denote the consumption of manufactured goods, services, and land by each consumer resided at location r, respectively. Therefore, the problem for a consumer who lives at location r

and works at t can be written as

$$\begin{aligned} w(t)exp(-\kappa|t-r|) &= p_m m(r) + p_s s(r) + q_H(r)l(r) \\ &= \min_{\{m,s,l\}} \{m + p_s s + q_H(r)l\} \end{aligned} \tag{2.3.2}$$

$$s.t. \qquad u(m,s,l) \geq \bar{U}$$

where $p_m(r)$, $p_s(r)$, and $q_H(r)$ denote the prices of manufactured goods, services, and land, while $\bar{U}$ is the reservation utility: the maximum utility a resident can get by locating elsewhere in the larger economy.

The Internal Structure of the City

Following the urban economics literature, I assume the city is monocentric with a CBD of positive radius and a surrounding residential ring. I take the city edge S as given. Specifically, I introduce an explicit internal structure within the CBD area. The service sector locates closest to the center, followed by the manufacturing sector. Some restrictions of parameters will be imposed to make this internal structure an equilibrium. Figure 2.2 shows the land-use map of the city. Let S_1 be the boundary between service and manufacturing sector and S_2 be the boundary between the manufacturing sector and residential area.

2.4 Equilibrium

Firms

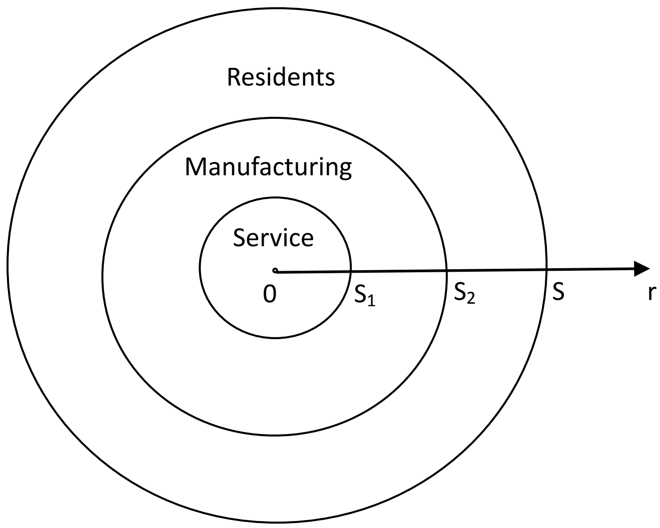
It is customary in urban economic theory to approach land use in terms of bid rent functions (Alonso (1964); Fujita (1989)). From the firm's problem in (2.3.1), the optimal choice of n conditional on locating at r is given by

$$n_i^*(r) = (\beta p_i exp(-\tau_i r)A_i/w(r))^{1/(1-\beta)}\,. \tag{2.4.1}$$

Then,

$$q_F^i(r) = \frac{1-\beta}{\beta}\left(\beta p_i exp(-\tau_i r)A_i w(r)^{-\beta}\right)^{1/(1-\beta)}, \tag{2.4.2}$$

Figure 2.2: Land-Use Map of the City



and $q_F^i(r)$ is the bid rent function for firms in industry i. The intuition is that a firm pays a lower rent if it is farther away from the city center.

Consumers

Every consumer at every location must receive the reservation utility $\bar{U}$ in equilibrium. Let $q_H(r)$ be the residential bid rent function: the maximum rent a worker would be willing to pay for a unit of land at location r. Solving the consumer's problem in (2.3.2),

$$m^*(r) = \alpha_1 w(t) exp(-\kappa|t-r|),$$
$$s^*(r) = \alpha_2 w(t) exp(-\kappa|t-r|)/p_s,$$
$$l^*(r) = \alpha_3 w(t) exp(-\kappa|t-r|)/q_H(r),$$
$$q_H(r) = \left(\alpha_1^{\alpha_1}\alpha_2^{\alpha_2}\alpha_3^{\alpha_3}p_s^{-\alpha_2}w(t)exp(-\kappa|t-r|)/\bar{U}\right)^{1/\alpha_3},$$

where $m^*(r)$, $s^*(r)$, and $l^*(r)$ are the optimal choices of consumption at location r. Intuitively, a resident pays a lower rent if she locates farther away from the center and if the utility she can get elsewhere is higher. Let $N(r)$ be the number of residents per unit of land at location r. In other words, $N(r)$ is the household density. Since each resident occupies $l(r)$ units of land, residential land market clearing condition will be $N(r)l(r) = 1$. Therefore, in equilibrium, $N(r) = 1/l^*(r)$. For an allocation to be feasible, we need a condition that all residents have to be accommodated somewhere in the city. This means that the integral of household density over the residential area must equal the total population, P,

$$P = \int_{S_2}^{S} N(r) 2\pi r dr = \int_{S_2}^{S} \frac{2\pi r}{l^*(r)} dr.$$

In addition, there is an arbitrage condition at the city edge S. Residential rent there must equal the rent in non-urban use, r_A, which is usually called "agricultural rent" in the literature, and is assumed not to vary with location.

The Internal Structure of the City

The analytical tractability is due to the fact that I can express all endogenous variables as negative exponentials, i.e., $x(r) = x(0)exp(-\phi_x r)$, where ϕ_x depends only on preference and technology parameters. Since wage rate $w(r)$ only depends on the location r, let us consider the business zone, with $r \in [0, S_2]$, first. Workers are free to move across sectors. They must be indifferent between working at different locations within the business zone. Wage can be then expressed as

$$w(r) = w(0)exp(-\kappa r) \qquad r \in [0, S_2).$$

Thus wages decline exponentially from the city center, reflecting that no one can gain by changing her job location. Wages closer to the city center are higher because the commuting costs are higher. Substituting this into equation (2.4.1) and using equation (2.4.2) yields the employment density

$$n_i(r) = n_i(0)exp\left(-\frac{\tau_i - \kappa}{1-\beta} r\right) \qquad r \in [0, S_2),$$

where $n_i(0) = (\beta p_i A_i / w(0))^{1/(1-\beta)}$. The firms' bid rent function in sector i is

$$q_F^i(r) = q_F^i(0)exp\left(-\frac{\tau_i - \kappa\beta}{1-\beta} r\right) \qquad r \in [0, S_2),$$

where $q_F^i(0) = \frac{1-\beta}{\beta}\left(\beta p_i A_i w(0)^{-\beta}\right)^{1/(1-\beta)}$. Note that this bid rent function is decreasing in r provided that $\tau_i - \kappa\beta > 0$.

Given that workers commute to the business zone earn the same regardless of where they work, it is convenient to imagine the place of work is at city center, $r = 0$. Then the maximum rent a worker is willing to pay and still get $\bar{U}$ is

$$q_H(r) = q_H(0)exp\left(-\frac{\kappa}{\alpha_3}r\right) \qquad r \in [0, S],$$

where $q_H(0) = \left(\alpha_1^{\alpha_1}\alpha_2^{\alpha_2}\alpha_3^{\alpha_3}p_s^{-\alpha_2}w(0)/\bar{U}\right)^{1/\alpha_3}$.

For the internal structure outlined in Figure 2.2 to be an equilibrium outcome, two conditions are needed at each boundary. At boundary S_1, the bid rent of service sector must be the same as that of manufacturing sector, $q_F^s(S_1) = q_F^m(S_1)$, and the slope of service sector's bid rent function must be steeper than the slope of manufacturing sector's bid rent function. These two conditions impose a constraint on the parameters τ_i. The slope of $q_F^i(r)$ can be written as $q_F^{i'}(r) = -\frac{\tau_i-\kappa\beta}{1-\beta}q_F^i(r)$. The conditions that $q_F^s(S_1) = q_F^m(S_1)$ and $q_F^{s'}(S_1) > q_F^{m'}(S_1)$ imply that $\tau_s > \tau_m$, which means that the service sector has a higher transport cost than the manufacturing sector. This ensures that service sector locates closest to the center, followed by the manufacturing sector. This is intuitive as services generally need face-to-face meeting, thus services involve travelling of people rather than shipping of goods. Hence this sector has more to gain from being closest to the center. Similarly, at boundary S_2, bid rent of manufacturing sector must be the same as the bid rent of residents, and the slope of the former must be steeper than that of the latter. The slope of $q_H(r)$ is $q_H'(r) = -\frac{\kappa}{\alpha_3}q_H(S_2)$. The conditions that $q_F^m(S_2) = q_H(S_2)$ and $q_F^{m'}(S_2) > q_H'(S_2)$ imply that $\kappa < \frac{\tau_m\alpha_3}{1-\beta+\alpha_3\beta}$. Since $\alpha_3, \beta < 1$, $\frac{\alpha_3}{1-\beta+\alpha_3\beta} < 1$. In addition, firms' rent bid functions are downward sloping. Therefore, for the spatial structure of the city to be an equilibrium, the restriction on parameters is

$$\kappa\beta < \tau_m < \tau_s.$$

In other words, when a firm decides its location, it faces a trade-off: by locating one unit closer to the city center, it saves shipping cost (captured by τ_i) but it also has to pay a higher wage for workers to commute longer (captured by $\kappa\beta$). The savings on shipping cost must outweigh the extra cost on wages paid for firms to locate in the area that is closer to the center. This ensures that firms would locate in the CBD and residents would locate farther away.

Equilibrium

Definition 1. *An equilibrium in this economy is a collection of continuous functions* $\{n_i(r), N(r), w(r), q_F^i(r), q_H(r)\}$, *for* $i = \{s, m\}$, *together with prices* $\{p_m, p_s\}$ *such that for all* r,

1. *wage arbitrage condition:* $w(r) = w(0)exp(-\kappa r)\ \ r \in [0, S_2)$,
2. $n_i(r)$ *and* $q_F^i(r)$ *are the employment density and bid rent functions defined by the firm's problem,*
3. $N(r)$ *and* $q_H(r)$ *are the residential density and bid rent function defined by the consumer's problem,*
4. $q_F^i(r)$ *and* $q_H(r)$ *satisfy equilibrium land rents condition: i.e., each piece of land goes to the highest-bidding use,*
5. *feasibility constraint:* $P = \int_{S_2}^{S} N(r) 2\pi r dr$,
6. *labor market clears at boundary* S_2,
7. *goods market clears at the center.*

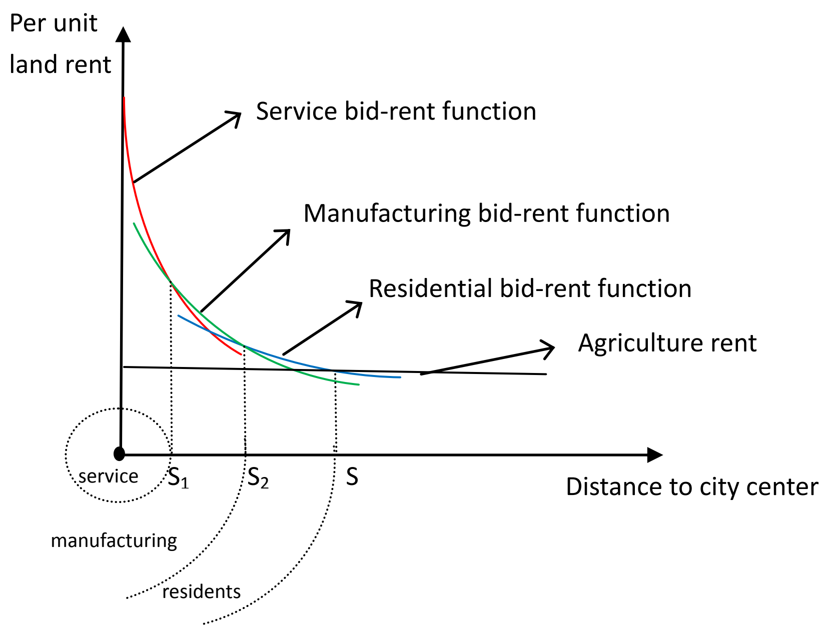
It is assumed that land is allocated to its highest-value use. Therefore, the equilibrium land rent at any location is the maximum of the bid rents there:

$$q(r) = \max\left[q_F^s(r),\, q_F^m(r),\, q_H(r),\, r_A\right] = \begin{cases} q_F^s(0)exp\left(-\frac{\tau_s - \kappa\beta}{1-\beta} r\right) & r \in [0, S_1) \\ q_F^m(0)exp\left(-\frac{\tau_m - \kappa\beta}{1-\beta} r\right) & r \in [S_1, S_2) \\ q_H(0)exp\left(-\frac{\kappa}{\alpha_3} r\right) & r \in [S_2, S] \\ r_A & r \in (S, \infty). \end{cases}$$

Figure 2.3 plots the equilibrium land rents for both the business zone - service and manufacturing sectors - and the residential zone.

The location of the commercial district boundary, S_2, is dentermined by the labor market clearing condition. At boundary S_2, each worker living at location r contributes $exp\left(-\kappa\left(r - S_2\right)\right)$ units of labor time, taking into account of the time lost in commuting

Figure 2.3: Equilibrium Land Rents



from r to S_2. The total supply of labor time at S_2 is thus $\int_{S_2}^{S} N(r)exp\left(-\kappa\left(r-S_2\right)\right)2\pi rdr$. Since the employment density at location t in the business zone is $n_i(t)$, labor time needed at boundary S_2 to fulfill this demand is thus $exp\left(\kappa\left(S_2-t\right)\right)n_i(t)$, taking into account of the time lost in commuting from S_2 to t. So the total time needed at S_2 to satisfy total labor demand inside the business zone is $\int_0^{S_1} 2\pi rn_s(t)exp\left(\kappa\left(S_2-t\right)\right)dt + \int_{S_1}^{S_2} 2\pi rn_m(t)exp\left(\kappa\left(S_2-t\right)\right)dt$. Therefore, equating labor demand and labor supply will give us

$$\begin{aligned}\int_{S_2}^{S} N(r)exp\left(-\kappa\left(r-S_2\right)\right)2\pi rdr &= \int_0^{S_1} 2\pi rn_s(t)exp\left(\kappa\left(S_2-t\right)\right)dt \\ &+ \int_{S_1}^{S_2} 2\pi rn_m(t)exp\left(\kappa\left(S_2-t\right)\right)dt.\end{aligned} \tag{2.4.3}$$

Turning to goods market clearing conditions, note that output per unit of land, taking into account of the shipping cost, can be written as

$$y_i(r) = A_i exp\left(-\tau_i r\right)n_i(r)^{\beta}.$$

Total supply of each type of goods at the city center is

$$\begin{aligned} s &= \int_0^{S_1} 2\pi r A_s exp\left(-\tau_s r\right) n_s(r)^\beta dr, \\ m &= \int_{S_1}^{S_2} 2\pi r A_m exp\left(-\tau_m r\right) n_m(r)^\beta dr. \end{aligned} \tag{2.4.4}$$

From the consumer's preference, the ratio of the consumption of the two types of goods is $\frac{s}{m} = \frac{\alpha_2 p_m}{\alpha_1 p_s}$. If one plugs in the expressions for s and m from the above, the relative prices can be pinned down, which governs the main result of this paper.

Equilibrium Characterization

To determine the equilibrium of the model, I show that the analysis is in terms of a closed city. That is, the city's population, P, is taken as given and the equilibrium determines the city's geographic size, S, and the utility it can deliver to its residents, $\bar{U}$. Since all functions are negative exponentials, the only unknowns are values of these functions at $r = 0$ and will be determined once $n_i(0)$ is determined. To see this, note that wage rate and bid rent functions at location $r = 0$ can be written as

$$\begin{aligned} w(0) &= \beta p_i A_i n_i(0)^{\beta-1}, \\ q_F^i(0) &= \left(1-\beta\right) p_i A_i n_i(0)^\beta = \tfrac{1-\beta}{\beta} w(0) n_i(0), \end{aligned}$$

and recall $q_F^m(S_2) = q_H(S_2)$, then the residential rent at $r = 0$ can be expressed as

$$q_H(0) = q_F^m(0) exp\left(-\frac{\alpha_3\tau_m - \alpha_3\kappa\beta - \kappa + \kappa\beta}{\alpha_3\left(1-\beta\right)} S_2\right).$$

Therefore, all of these variables at $r = 0$ are functions of $n_i\left(0\right)$.

Using the expressions for $q_H(r)$, $n_i(r)$, and $l(r)$, the labor market clearing condition in (2.4.3) can be written as

$$\begin{aligned} & exp\left(-\tfrac{\alpha_3\tau_m - \alpha_3\kappa\beta - \kappa + \kappa\beta}{\alpha_3(1-\beta)} S_2\right) \int_{S_2}^{S} r exp\left(-\tfrac{\kappa}{\alpha_3} r\right) dr \\ &= \tfrac{\alpha_3\beta}{1-\beta} exp\left(\tfrac{\tau_s - \tau_m}{1-\beta} S_1\right) \int_0^{S_1} r exp\left(-\tfrac{\tau_s - \kappa\beta}{1-\beta} r\right) dr \\ &\quad + \tfrac{\alpha_3\beta}{1-\beta} \int_{S_1}^{S_2} r exp\left(-\tfrac{\tau_m - \kappa\beta}{1-\beta} r\right) dr. \end{aligned} \tag{2.4.5}$$

This is one equation that only depends on the boundaries, S, S_1, and S_2. Plugging in the goods market clearing conditions in (2.4.4) into the equation of relative prices, we get

$$exp\left(\frac{\tau_s-\tau_m}{1-\beta}S_1\right)\frac{\int_0^{S_1} rexp\left(-\frac{\tau_s-\kappa\beta}{1-\beta}r\right)dr}{\int_{S_1}^{S_2} rexp\left(-\frac{\tau_m-\kappa\beta}{1-\beta}r\right)dr}=\frac{\alpha_2}{\alpha_1}, \qquad (2.4.6)$$

which only depends on boundaries S_1 and S_2.

Higher Relative Price in Larger Cities

Recall that at boundary S_1, $q_F^s(S_1)=q_F^m(S_1)$. Using expressions for $q_F^i(r)$ and $n_i(0)$, the relative price of services is

$$\left(\frac{p_sA_s}{p_mA_m}\right)^{1/(1-\beta)}=exp\left(\frac{\tau_s-\tau_m}{1-\beta}S_1\right). \qquad (2.4.7)$$

Since $\tau_s>\tau_m$, as long as A_s/A_m is constant, the relative price of services is increasing in S_1. Intuitively, it is equally profitable to produce services and manufactured goods at the boundary S_1. The farther out the boundary, the higher the transport cost, which affects the service sector disproportionately more. And this has to be compensated by the higher price of services. The main result of the paper is to show how a change in population, P, affects the boundary S_1.

The following analysis takes several steps as outlined below. First, I will prove that if the boundary between manufacturing sector and residential area, S_2, is taken as given, then S_1, the boundary between service and manufacturing sector, is strictly increasing in S_2. Also, if both population, P, and city edge, S, are taken as given, then S_2 is strictly increasing in S. Second, I show that given productivity A_i, the city size, $S(A_i,P)$, is strictly increasing in population, P. To see this, I first demonstrate that given A_i and S, the employment density at the city center, $n_i(0)$, and bid rent functions, $q_F^m(r)$, $q_H(r)$, are increasing in P. In addition, given A_i and P, these three functions, $n_i(0)$, $q_F^m(r)$, and $q_H(r)$, are decreasing in S. Finally, I show that $q_H(S;A_i,P)$ is strictly decreasing in S and increasing in P.

Lemma 1. *For each $S_2>0$, (2.4.6) uniquely determines $S_1(S_2)\in(0,S_2)$. Furthermore, $S_1(S_2)$ is strictly increasing in S_2.*

Proof. See Appendix B. □

The intuition is that equation (2.4.6) implicitly defines S_1 as a function of S_2, i.e., there is a unique S_1 corresponding to each S_2 and it is strictly increasing in S_2. In other words, if the boundary between manufacturing sector and residential area is farther away from the city center, then the boundary between service and manufacturing sector must also increase. To see the relation between S_2 and S, rearraNging (2.4.6) and plugging into (2.4.5) can further simplify (2.4.5) to

$$\begin{aligned} & exp\left(-\frac{\alpha_3\tau_m-\alpha_3\kappa\beta-\kappa+\kappa\beta}{\alpha_3(1-\beta)}S_2\right)\int_{S_2}^{S} rexp\left(-\frac{\kappa}{\alpha_3}r\right)dr \\ = & \frac{\alpha_3\beta}{1-\beta}\left(1+\frac{\alpha_1}{\alpha_2}\right)exp\left(\frac{\tau_s-\tau_m}{1-\beta}S_1(S_2)\right)\int_0^{S_1(S_2)} rexp\left(-\frac{\tau_s-\kappa\beta}{1-\beta}r\right)dr. \end{aligned} \tag{2.4.8}$$

Lemma 2. *For each $S>0$, the expression above uniquely determines $S_2(S)\in(0,S)$. Furthermore, $S_2(S)$ is strictly increasing in S.*

Proof. See Appendix B. □

As city edge moves outwards, so does the boundary between the business zone and residential area. Lemma 1 and Lemma 2 together give the relation between the three boundaries of the city, which will be useful in the proof of the main result later. The next part is to show the relation between population and the boundaries. From the feasibility constraint, $P=\int_{S_2}^{S} N(r)2\pi r dr$, expressions for $l(r)$, $q_H(0)$, and equation (2.4.8), the employment density $n_i(0)$ can be written as

$$n_m(0)=\frac{P}{2\pi\left(1+\frac{\alpha_1}{\alpha_2}\right)}\frac{\int_{S_2}^{S} rexp\left(-\frac{\kappa}{\alpha_3}r\right)dr}{exp\left(\frac{\tau_s-\tau_m}{1-\beta}S_1\right)\int_0^{S_1} rexp\left(-\frac{\tau_s-\kappa\beta}{1-\beta}r\right)dr\int_{S_2}^{S} rexp\left(-\frac{\kappa(1-\alpha_3)}{\alpha_3}r\right)dr}, \tag{2.4.9}$$

$$n_s(0)=exp\left(\frac{\tau_s-\tau_m}{1-\beta}S_1\right)n_m(0). \tag{2.4.10}$$

If A_i and S are held constant, a change in P will change $n_i(0)$ proportionally. Recall that the equilibrium of the model is determined by $n_i(0)$. Therefore, the following proposition summarizes the effects of a change in population:

Proposition 1. *If A_i and S are held constant, (i) employment density $n_i(0)$ change proportionately with P, (ii) elasticity of rents $q_F^m(r)$ and $q_H(r)$ in any location with respect to P is β, (iii) elasticity of wage in any location with respect to P is $\beta-1$.*

Turning to the effects of a change in the land supply, let A_i and P be constant. Then from (2.4.9) and (2.4.10) it implies that $n_m(0)$ is decreasing in S. This can be obtained by using Lemma 1, Lemma 2 and also Lemma 2 from Chatterjee and Eyigungor (2013), which states an important algebraic result. Similarly, $n_s(0)$ is also decreasing in S. The intuition is that the employment density at the city center is lower in a more spread-out city. Therefore, it follows that:

Proposition 2. *If A_i and P are held constant, the employment density $n_i(0)$ and rents $q_F^m(0)$, $q_H(0)$ are decreasing in S.*

Proof. See Appendix B. □

Proposition 2 implies that as the city's geographic size increases, the rent at the city center decreases. Now the effects of a change in population, P, and the effects of a change in land supply, S, are established. It remains to show the effects of a change in population on the city size, S, namely, the determination of S and $\bar{U}$, given A_i and P. Since the agricultural rent outside the city is r_A, the city edge, S, is determined by

$$q_H(S; A_m, P) = r_A,$$

where $q_H(S; A_m, P)$ is the rent at the city edge when the TFP in the manufacturing sector is A_m and the population is P. The following Lemma gives the relation between $q_H(S; A_m, P)$ and S.

Lemma 3. *$q_H(S; A_m, P)$ is strictly decreasing in S and strictly increasing in A_m and P.*

Proof. See Appendix B. □

Holding other variables constant, rent at the city edge falls with the city size, S, because people living at the boundary earn the least due to the large amount of time lost in commuting to work. Given Lemma 3, for any A_i, P, and r_A, there is a unique S, that solves $q_H(S; A_m, P) = r_A$. Let the solution be $S(A_m, P)$. Then immediately from Lemma 3:

Proposition 3. *$S(A_m, P)$ is strictly increasing in P.*

Therefore, the main result of this paper is established: larger cities have higher relative prices. The logic can be seen as follows: by Proposition 3, cities with higher population have a larger city size. By Lemma 1 and Lemma 2, as the city is more spread-out, so does the boundary between service and manufacturing sector (S_1). By equation (2.4.7), as long as A_s/A_m is constant, the relative price of services is increasing in S_1. This explains why cities with higher population have higher relative price.

2.5 Conclusion

This paper has two important contributions. First, it documents the empirical facts about price differences of tradable and non-tradable goods across cities. Previous studies have largely focused on aggregate price index and housing or land prices. While theories in NEG predict that price of tradable goods is lower in larger cities, recent empirical evidence by Handbury and Weinstein (2014) only contains data of food items. This paper uses detailed component data for 56 individual goods and services across 209 U.S. cities to construct price indices for both tradable and non-tradable goods and services. I find that contrary to existing theories, price of tradable goods is higher in larger cities. Price of non-tradable goods, excluding land, is also significantly higher in larger cities. In particular, a one log-unit rise in city size is associated with a 3.4% increase in non-tradable price index but only a 1.2% increase in tradable price index.

To address this cross-city price difference, this paper proposes a spatial model of cities in which an explicit internal structure is introduced: service sector locates closest to the city center, followed by manufacturing sector, and then by residents. The difference in transport costs ensures this spatial structure. All agents face a trade-off: by locating closer to the center, they save transport or commuting cost but they have to pay a higher land price. In equilibrium, all agents choose their optimal location. The equilibrium defines the boundaries of the city. As population grows, the city edge increases. This leads to an increase in the boundary between service and manufacturing sector, which affects service sector proportionately more, because service sector has a higher transport cost. Therefore, the relative price of services is higher in larger cities.

Chapter 3

Sudden Stops, Financial Frictions, and the Banking Sector

3.1 Introduction

Last decade has witnessed several episodes in which the interest-rate driven capital flows affected the economic developments of several emerging market countries. After the 1994 Mexican devaluation, the Russian default and Asian crises in 1997-1998, Latin American and Asian countries experienced how the increase of interest rates gave rise to deep recessions, unemployment, and financial turmoil. These financial crises of the last decade in emerging economies have typically been accompanied by large falls in total factor productivity. Recent research shows that the drop in TFP attributed to the GDP declines in these sudden stop episodes. Investigating the forces behind these movements in total factor productivity is crucial to understand the real effects of financial crises. The effects of interest rate shocks that are independent of domestic economic developments have been studies empirically: assessing the relative importance of internal and external factors to explain the surge of capital flows to Asian and Latin American countries during the 1990's, Calvo, Leiderman, and Reinhart (1996) conclude that the cyclical movement in world interest rates is the most critical element that explains those capital flows and the subsequent growth stimulus. Theoretical work, however, has neglected the importance of financial intermediaries in the borrowing-lending process when a economy is hit by a shock to the world interest rate. In this paper, I explore the role of financial frictions with a banking sector in exacerbating inefficiencies and explaining the drop in measured TFP.

More specifically, I build a small open economy model in which banks are the only domestic agents with access to international capital markets. Households own all banks and firms in the economy and their assets are bank loans and physical capital. Households make consumption, investment, and borrowing decisions. There is one tradable sector, which uses capital, labor and intermediate goods in a constant returns to scale technology to produce a single final good. The final good is used for consumption, investment and the production of intermediate goods. The production process is subject to a working capital constraint that requires firms to hold non-interest-bearing assets to finance a fraction of the purchase of intermediate goods each period. The representative bank borrows from international capital markets and lends to domestic households and firms. The bank is subject to a reserve requirement and pays and charges interest in advance. The economy exports and saves in final goods. Besides intertemporal adjustment costs for capital, the financial constraint on the purchase of intermediate goods is the only friction in the model.

An exogenous increase in the world interest rate has a twofold effect. First, it increases the domestic interest rate through the bank's intermediation. The bank acts as an amplification mechanism of interest rate shocks: a one percent increase in world interest rate is translated to more than one percent increase in domestic interest rate. Second, as the domestic interest rate rises, it increases the wedge between the producer cost and the user cost of intermediate goods. Firms, with working capital financing needs, will experience an increase in the cost of production. This worsens the misallocation and generates an endogenous fall in TFP and output.

The model is calibrated to the Mexican economy prior to the sudden stop of 1994 and subject to the world interest rate shocks observed during the sudden stop. The model generates a 5.9 percent fall in output, though a larger fall compared to the data. It delivers a TFP fall by 4.9 percent, accounting for 74 percent of the observed decline in TFP in the data. The model is also consistent with a current account reversal, investment, and bank loans to the private sector, as observed in the data.

A distinguishing aspect of the model is that it features a SOE in which a neoclassical banking system intermediates the inflows of foreign capital and firms have to finance their working capital. The most closely related paper is Pratap and Urrutia (2012), who also explore the role of financial frictions in exacerbating existing inefficiencies and explaining the drop in TFP. This paper is similar in that the working capital constraint affects the purchase of intermediate goods. There are two main differences. First, their model examines the effects of a change in domestic interest rate on output and productivity. In addition, they do not explicitly model a bank as a financial intermediary. Another closely related paper is Oviedo (2003, 2005), who extends the neoclassical growth model to include financial intermediation. His paper, however, focuses on the interest-driven business cycles and volatility of domestic credits and capital flows.

This paper borrows a key insight from the literature that shows the financial conditions and the availability of external financial capital in emerging countries are, to a large extent, dependent on factors external to the domestic economy, such as world interest rate. Calvo, Leiderman, and Reinhart (1993, 1996) study the capital inflows in Latin America in the 1990s and find that much of the inflows were driven by factors external to the region. Calvo and Mendoza (2000) study the likely scenario that international investors follow the 'market' rather than assessing each country's fundamentals. Uribe and Yue (2006) investigate how emerging-country spreads respond to changes in the world interest rate. They document that U.S. interest rate shocks explain about 20% of movements in aggregate activity in emerging countries at business-cycle frequency. In this paper, I build a model to demonstrate the effects of a change in world interest rate and assess its plausibility to explain the effects of financial crises.

This paper also contributes to the literature on financial frictions and sudden stops in emerging economies. Mendoza (2010) and Mendoza and Yue (2008) use financial frictions as a device to amplify the economy's aggregate response to a sequence of bad realizations of exogenous TFP shocks. In my model, financial frictions can endogenously generate a large fall in TFP, which is more in line with Pratap and Urrutia (2012). In addition, Neumeyer and Perri (2005) propose modifying the standard model to introduce a demand for working capital. Since firms have to pay for the use of factors of production before getting their sale proceeds, the interest rate is part of the cost of employing inputs. In their model, any output drop generated by an increase in interest rates is due to a decline in the labor supply and equilibrium employment. In my paper, the financial friction affects the purchase of intermediate goods instead of the wage bill.

In what follows, Section 3.2 documents the empirical findings on the importance of a banking sector in emerging economics, especially during sudden stop episodes. Section 3.3 introduces the model and derives equilibrium conditions for numerical analysis. Section 3.4 presents a numerical exercise of the model: calibrating to the Mexican economy before the 1995 crisis. It also reports results from the numerical experiment. Finally, Section 3.5 concludes.

3.2 Empirical Findings

In emerging economies, does the banking sector play an important role during sudden stop episodes? This section documents two major facts about the importance of banks for the macroeconomic performance of emerging economies. A significant portion of the domestic credits is provided by the banking sector. For example, 60% of domestic credits was provided by banks in Korea during 1990s, while in Mexico it was 40%. Moreover, a positive contemporaneous correlation between GDP and Bank loans was seen in both Mexico and Argentina.

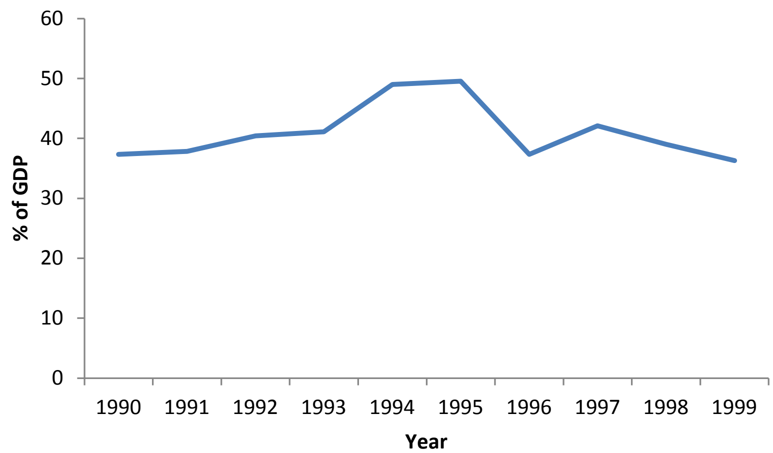
3.2.1 Domestic Credits Provided by Banks

The banking system is a central element in the process of financial intermediation in most developing countries, and domestic capital markets play an almost insignificant role. This fact has been documented by Gurley and Shaw (1960), who observe that in the earlier stages of financial development, commercial banking is the main form of intermediation. Beck, Demirguc-Kunt, and Levine (2000) also show that private bonds markets capitalization is around 4% of the GDP, and total private credit from financial intermediaries is 20% of the GDP in low and lower-middle income countries.

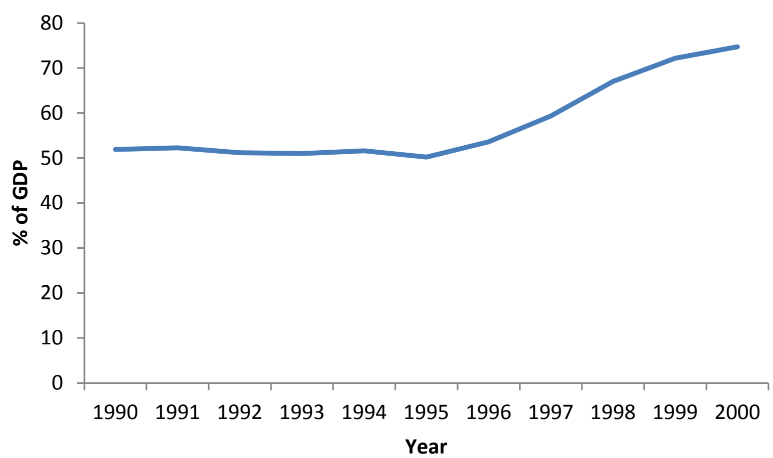
Figure 3.1 shows the portion of domestic credits provided by banks for Mexico and Korea. The proportion of domestic credits financed by banks in Mexico was over 40% of the GDP in the 1990s. In particular, during sudden stops in 1994-1995, it went up to almost 50%. A similar pattern is also seen in Korea, as bank loans accounted for 50% of the GDP, which surged to about 60% during 1997-1998 sudden stops. Since banks play an important role in emerging economies, when it is difficult to finance through other channels, firms rely on banks even more during crisis.

Figure 3.1: Domestic Credits Provided by Banks

(a) Mexico



(b) Korea



3.2.2 Bank Loans and GDP

Since the access to international borrowing and lending is the distinguishing characteristic of open economies, the cost of borrowing affects the economic prosperity of emerging countries in the short run. For instance, the negative correlation between interest rates and overall economic activity in emerging countries has been documented by recent research such as Neumeyer and Perri (2005) and Uribe and Yue (2006). These studies find that the correlation between interest rates and output is negative and may exceed (in absolute value) 0.5 in emerging countries.

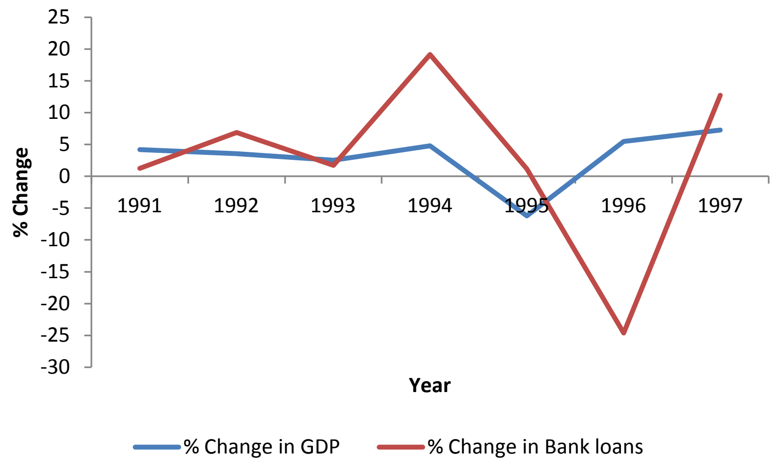
It is also not surprising to see the co-movement between bank loans and GDP, as shown in Figure 3.2. For both Mexico and Argentina, the graph shows that the change in GDP and the change in bank loans move together. This positive contemporaneous correlation between GDP and Bank loans has been documented in the literature. Oviedo (2003) investigates this co-movement between bank loans and GDP for Argentina and finds a correlation equal to 0.64. Sharif (2010) uses a sample of 19 countries (both emerging and advanced economies) to show that bank loan supply fluctuations are associated with disturbances in GDP.

3.3 The Model

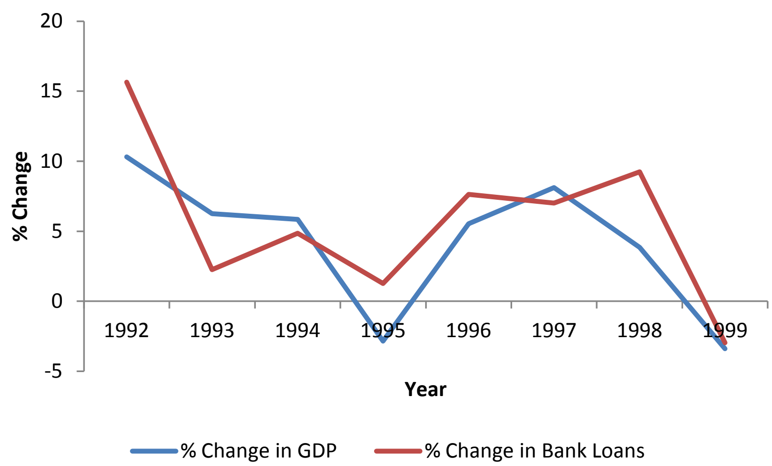
Consider a small open economy with four type of agents, namely, households, firms, intermediate good producers and banks. Households do not have direct access to international financial markets and their assets are physical capital and bank loans. Households own all banks and firms in the economy but perfect competition cuts down banks' and firms' profits to zero. The firm produces output by renting capital k_t and buying labor n_t from households and purchasing intermediate goods from intermediate goods producers. I introduce the financial friction as a working capital requirement for production. The working capital constraint implies that every period the firm must hold non-interest-bearing assets to finance a fraction θ of intermediate goods. All prices are in terms of the final good.

Figure 3.2: Bank Loans and GDP Co-Movement

(a) Mexico



(b) Argentina



Consumers

The infinitely lived representative consumer is endowed with one unit of labor, which is supplied inelastically. Each period, the consumer consumes the final good c_t, saves/borrows from banks l_t^h, and invests in capital k_t. The interest on bank loans is paid in advance at domestic rate r_t^l. The consumer's problem can be written as

$$\max_{\left\{c_t, l_t^h, k_{t+1}\right\}} \sum_{t=0}^{\infty} \beta^t \frac{c_t^{1-\sigma} - 1}{1-\sigma}, \tag{3.3.1}$$

subject to the budge constraint

$$c_t + x_t + l_t^h r_t^l \leq w_t + r_t^k k_t + \left(l_t^h - l_{t-1}^h\right), \tag{3.3.2}$$

where the consumer's source of resources includes net borrowing from banks $\left(l_t^h - l_{t-1}^h\right)$ and labor and capital-rental income, which depend on the wage rate w_t and the rental rate of capital r_t^k . Resources are spent in consumption and investment, c_t and x_t, respectively, and in interest payments, which depend on the amount borrowed, l_t^h , and the bank lending rate, r_t^l . Raising the stock of capital from k_t at time t to k_{t+1} at time $t+1$ requires incurring in adjustment costs whose size is controlled by the value of the parameter ϕ. Let δ represent the depreciation rate. The law of motion of the capital stock can then be written as:

$$x_t = k_{t+1} - (1-\delta) k_t + \frac{\phi}{2} \left(\frac{k_{t+1} - k_t}{k_t}\right)^2. \tag{3.3.3}$$

Given initial conditions k_0 and l_{-1}^h, the description of consumer's problem is complete. The optimality conditions include the budget constraint holding with equality and

$$\beta \left(\frac{c_{t+1}}{c_t}\right)^{-\sigma} = 1 - r_t^l, \tag{3.3.4}$$

$$\left(1 - r_t^l\right) \left(r_{t+1}^k + 1 - \delta + \phi \left(\frac{k_{t+2} - k_{t+1}}{k_{t+1}}\right) \frac{k_{t+2}}{k_{t+1}^2}\right) = 1 + \frac{\phi}{k_t} \left(\frac{k_{t+1} - k_t}{k_t}\right). \tag{3.3.5}$$

The transitivity condition indicates that

$$\lim_{t\to\infty} E_t \left[c_t^{-\sigma}\left(k_t - l_t^h\right)\right] = 0.$$

Equations (3.3.4) and (3.3.5) are the Euler equations for bank loans and capital, respectively. It is interesting to note that the consumer's budget constraint (3.3.2) characterizes the case in which the interest rate is known and paid at the borrowing time. This timing is adopted by Diaz-Gimenez, Prescott, Fitzgerald, and Alvarez (1992), from whom this paper borrows the formulation of the banking problem below.

Firms

Competitive firms combine capital, labor and intermediate goods in a constant returns to scale technology to produce a single final good, which is used for consumption, investment and the production of intermediate goods,

$$Y_t = \left(k_t^{\alpha} n_t^{1-\alpha}\right)^{\varepsilon} m_t^{1-\varepsilon}.$$

The price of final good is used as the numeraire. Following Uribe and Yue (2006), the production process is subject to a working capital constraint that requires firms to hold non-interest-bearing assets to finance a fraction of the purchase of intermediate goods each period,

$$\eta_t \geq \theta p_t^m m_t \qquad \theta \geq 0, \tag{3.3.6}$$

where η_t denotes the amount of working capital held by the firm at the end of each period t.

Assuming interest is paid in advance, let l_t^y denote the bank loans demanded by the firm. The debt position of the firm evolves according to the following expression

$$l_t^y = l_{t-1}^y + r_t^l l_t^y - Y_t + w_t n_t + r_t^k k_t + p_t^m m_t + \pi_t - \eta_{t-1} + \eta_t,$$

where π denotes profits of firms distributed to consumers, and $r_t^l l_t^y$ represents the amount of interest paid in advance. Rearrange the above equation to get

$$\left(1-r_t^l\right)l_t^y = l_{t-1}^y - Y_t + w_t n_t + r_t^k k_t + p_t^m m_t + \pi_t - \eta_{t-1} + \eta_t.$$

Define the firm's total net liabilities at the end of period t as $a_t = l_t^y - \eta_t$. Then, we can rewrite the above equation to get

$$\left(1-r_t^l\right)a_t = a_{t-1} - Y_t + w_t n_t + r_t^k k_t + p_t^m m_t + \pi_t + r_t^l \eta_t.$$

Substitute equation (3.3.6) to get

$$\left(1-r_t^l\right)a_t = a_{t-1} - Y_t + w_t n_t + r_t^k k_t + p_t^m \left(1+\theta r_t^l\right) m_t + \pi_t.$$

The firm's objective is to maximize the present discounted value of the stream of profits distributed to its owners, i.e., the consumers. That is,

$$\max E \sum_{t=0}^{\infty} \beta^t \pi_t.$$

Assume firms start out with no liabilities, $a_0 = 0$, then an optimal plan consists of holding no liabilities at all times ($a_t = 0 \ \forall t \geq 0$), with distributed profits given by

$$\pi_t = Y_t - w_t n_t - r_t^k k_t - p_t^m \left(1+\theta r_t^l\right) m_t.$$

It is clear from the optimal conditions below and the Cobb-Douglas production technology that one can conclude that profits are zero at all times ($\pi_t = 0 \ \forall t$). The firm's problem can then be rewritten as

$$\max_{\{k_t, n_t, m_t\}} Y_t - w_t n_t - r_t^k k_t - p_t^{\tilde{m}} m_t,$$

where $p_t^{\tilde{m}} = p_t^m \left(1+\theta r_t^l\right)$ is the user price of the intermediate goods. Define $\frac{p_t^{\tilde{m}}}{p_t^m} = 1+\theta r_t^l$ to be the wedge between producer price and the user price of intermediate goods. When $\theta > 0$, the working capital constraint acts like a tax on inputs. During sudden stops, an increase in r_t^l will increase the wedge , which worsens the allocative inefficiency by taking the production of intermediate goods further away from the optimal. The firm's optimality conditions are

$$w_t = \varepsilon \left(1 - \alpha\right) \frac{Y_t}{n_t}$$

$$r_t^k = \alpha \varepsilon \frac{Y_t}{k_t}$$

$$m_t = \left(1 - \varepsilon\right) \frac{Y_t}{p_t^{\tilde{m}}}$$

Intermediate Goods Producers

The intermediate goods producers transform $\tilde{m}_t$ units of the final goods into intermediate goods m_t using a linear technology, i.e.,

$$m_t = A_m \tilde{m}_t.$$

The intermediate goods producers' problem can be written as

$$\max_{\tilde{m}_t} p_t^m m_t - \tilde{m}_t,$$

which implies

$$p_t^m = \frac{1}{A_m}.$$

Banks

The representative bank is the only domestic agent borrowing and lending in international capital markets. It is subject to a reserve requirement and pays and charges interest in advance. The bank's static optimization problem consists of maximizing its end-of-period assets:

$$\max_{\{l_t, s_t, b_t\}} l_t + s_t - b_t,$$

subject to a cash flow constraint, a reserve-requirement constraint, and non-negative constraints, respectively,

$$l_t \left(1 - r_t^l\right) + s_t + \eta^b b_t + \eta^l l_t \leq b_t \left(1 - r_t\right), \qquad \eta^b, \eta^l > 0$$

$$s_t \geq \tau b_t,$$

$$l_t, s_t, b_t \geq 0,$$

where l_t stands for total loans, s_t for bank reserves, b_t for bonds issued by the bank in world financial markets, r_t for the world interest rate, and τ for the reserve requirement coefficient. Following Diaz-Gimenez, Prescott, Fitzgerald, and Alvarez (1992), there is a constant cost, η^b, per unit of bond issued by the bank in the world financial markets, and a constant cost, η^l, per unit of value loaned.

The bank finds it optimal to set the reserve requirement as equality, $s_t = \tau b_t$. The remaining optimality conditions imply that the spread is implicitly given by the following expression

$$r_t^l = \eta^l + \frac{r_t + \eta^b}{1-\tau}. \tag{3.3.7}$$

This expression shows that the domestic interest rate rises with the reserve requirement coefficient and the intermediation costs η^b and η^l. Note that we have $dr_t^l/dr_t = 1/(1-\tau)$, so the bank acts as an amplification mechanism of world interest rate shocks when $\tau > 0$. Free access to the intermediation technology drives profits down to zero, i.e., $l_t = (1-\tau)\, b_t$.

Equilibrium

The competitive equilibrium in this economy consists of a sequence of state contingent allocations for each consumer $\left\{c_t, n_t, k_{t+1}, l_t^h\right\}_{t=0}^{\infty}$; a sequence of contingent allocations for each firm $\{k_t, n_t, m_t\}_{t=0}^{\infty}$ and for each intermediate goods producer $\{\tilde{m}_t\}_{t=0}^{\infty}$; a sequence of contingent allocations for each bank $\{l_t, s_t, b_t\}_{t=0}^{\infty}$; and a sequence of prices $\left\{r_t^l, r_t^k, w_t, p_t^m, r_t\right\}_{t=0}^{\infty}$ such that,

1. The allocation $\left\{c_t, n_t, k_{t+1}, l_t^h\right\}_{t=0}^{\infty}$ solves the representative consumer's problem, i.e., it maximizes the expected lifetime utility in (3.3.1) subject to budget constraint in (3.3.2) and the law of motion of capital in (3.3.3).

2. The allocation $\{k_t, n_t, m_t\}_{t=0}^{\infty}$ maximizes the representative firm's profit in every

period given the sequence of prices. Similarly, the allocation $\{\tilde{m}_t\}_{t=0}^{\infty}$ maximizes the intermediate goods producer's profit in every period.

3. The allocation $\{l_t, s_t, b_t\}_{t=0}^{\infty}$ gives the bank maximized assets at the end of every period subject to the cash flow constraint, the reserve-requirement constraint, and non-negative constraints.

4. The following markets clear in every period:

   (a) for the final good

   $$Y_t = c_t + k_{t+1} - (1-\delta)\,k_t + \frac{\phi}{2}\left(\frac{k_{t+1}-k_t}{k_t}\right)^2 + \tilde{m}_t + \eta^b b_t + \eta^l l_t + NX_t.$$

   In other words, final goods are used for consumption, capital investment, intermediate goods production, paying for costs of bonds and loans by the bank, and net export.

   (b) for labor

   $$n_t = 1.$$

   (c) for loans

   $$l_t = l_t^h + l_t^y = l_t^h + \theta p_t^m m_t.$$

Macroeconomic Aggregates

GDP in this economy can be expressed as

$$\begin{aligned} GDP_t &= Y_t - p_t^m m_t \\ &= w_t + r_t^k k_t. \end{aligned}$$

The real GDP at constant prices can be defined as

$$RGDP_t = Y_t - p_0^m m_t,$$

and aggregate TFP can be expressed as

$$TFP_t = \frac{RGDP_t}{k_t^{\alpha}}.$$

3.4 Numerical Analysis

3.4.1 Calibration

The model is calibrated to match the key features of the Mexican economy on the eve of the crisis. Table 3.1 gives the calibrated parameters and the statistics they match.

Some of these parameters deserve discussion. For the production function parameters, I use the input and output tables reported in Kehoe and Ruhl (2009). The two ratios that suffice to identify production function parameters are

$$\frac{Intermediates\,Consumption}{Value\,Added} = \frac{1-\varepsilon}{\varepsilon} = 0.7793,$$

$$\frac{Employee\,Compensation}{Value\,Added} = \frac{(1-\alpha)\,\varepsilon}{\varepsilon} = 0.62.$$

These two equations imply that $\varepsilon = 0.562$ and $\alpha = 0.4$. The parameter θ, which governs the amount of non-interest-bearing assets to finance a fraction of the purchase of intermediate goods each period, is a key parameter of the model. Recall that when $\theta > 0$, the working capital constraint acts like a tax on inputs. The higher the value of θ, the larger the wedge between producer price and user price of intermediate goods. Following Pratap and Urrutia (2012), who estimate this parameter from firm level data and NIPA data, I take the value of $\theta = 0.7$. I set $\sigma = 2$, which gives an intertemporal elasticity of substitution of consumption of 0.5. The world interest rate, r, outside the crisis is set to 5 percent, which is consistent with average world real interest rates. The discount factor β is then set to $1/\left(1+r\right)$. As in Diaz-Gimenez, Prescott, Fitzgerald, and Alvarez (1992), the bank reserve requirement τ is set to 0.01.

The parameters A_m, l_0^h, and ϕ are calibrated to the steady state. In particular, I compute a steady state equilibrium for the model economy and jointly match two targets: investment to output ratio and trade balance in 1994. I do not claim that the Mexican economy was in a steady state in 1994, but calibrating to a steady state is a means to get initial conditions for the numerical experiment in the next section. The parameter for the adjustment cost of capital, ϕ, is calibrated to match the investment to GDP ratio in 1995.

Table 3.1: Calibrated Parameters

Statistic	Target	Parameter	Value
Ratio of Intermediates to Value Added	0.7793	ε	0.562
Share of Labor in Value Added	0.62	α	0.4
Fraction of Intermediates Financed by Working Capital	0.7	θ	0.7
Depreciation Rate		δ	0.05
Intertemporal Elasticity of Substitution	0.5	σ	2.0
World Interest Rate	0.05	r	0.05
Discount Factor		β	0.952
Ratio of Investment to GDP	0.2	A_m	0.2775
Ratio of Net Exports to GDP	-0.05	l_0^h	-0.2486
Investment to GDP Ratio in 1995	0.15	ϕ	2.4
Bank Reserve Requirement		τ	0.01
Bank per unit Fixed Cost for Loans		η^l	0.049
Bank per unit Fixed Cost for Bond Issued		η^b	0.01

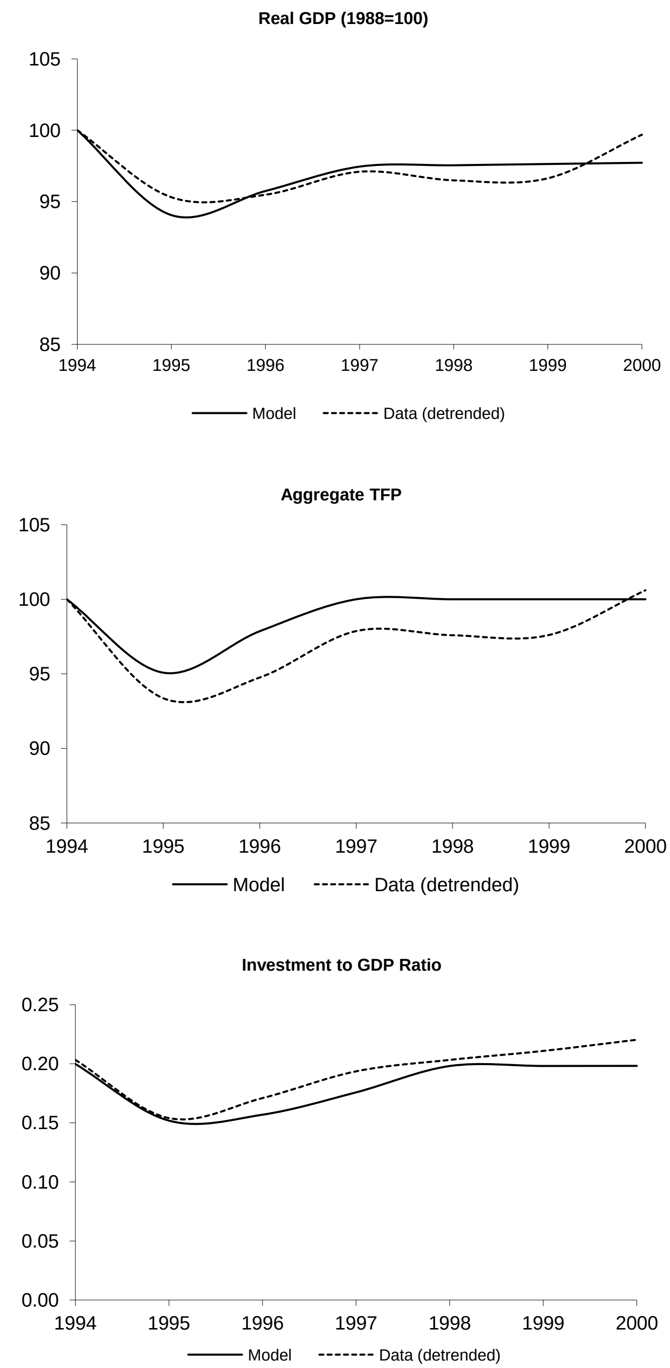
3.4.2 Numerical Experiment

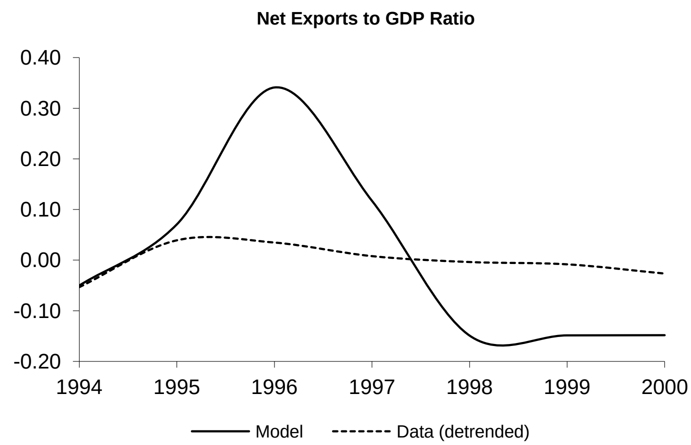
This section analyzes the effects of a change in the world interest rates on the Mexican economy during and after sudden stops. I begin the experiment by calibrating the economy to a steady state that matches the key features of the Mexican economy in 1994. Then world interest rate is increased to 12.7 percent in 1995 and 8.2 percent in 1996, as observed in the data. The purpose of this experiment is to examine the amplification mechanism of a world interest rate shock through the bank's intermediation.

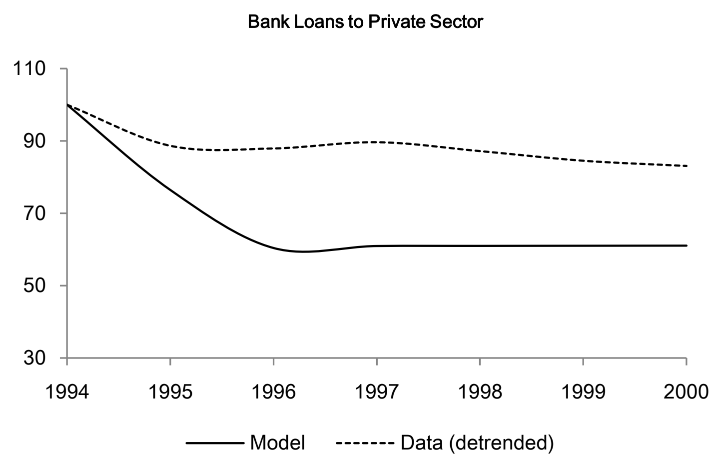
Figure 3.3 shows the resulting response of aggregates after the world interest rate shock. The top two panels give the fall in GDP and TFP. Since the labor supply is taken as exogenous and working capital constraint only affects the purchase of intermediate goods, I compare the model's predictions of macroeconomic aggregates per worker. The model generates a 5.9 percent fall in output, a larger fall compared to the data, which has only 4.7 percent decrease. The TFP falls by 4.9 percent, accounting for 74 percent of the observed decline in TFP in the data.

The intuition can be seen in equation (3.3.7): a shock to the world interest rate increases the domestic interest rate. Since $\tau > 0$, the bank acts as an amplification mechanism of world interest rate shocks. Recall that the wedge between producer price and the user price of intermediate goods, i.e., $\frac{p_t^{\tilde{m}}}{p_t^m} = 1 + \theta r_t^l$, represents the allocative

Figure 3.3: Numerical Results in the Model Economy. *(cont.)*




Net Exports to GDP Ratio
0.40
0.30
0.20
0.10
0.00
-0.10
-0.20
1994
1995
1996
1997
1998
1999
2000
Model
Data (detrended)


Bank Loans to Private Sector
110
90
70
50
30
1994
1995
1996
1997
1998
1999
2000
Model
Data (detrended)

inefficiency generated by the working capital constraint. An increase in domestic interest rate r_t^l will take the production of intermediate goods further away from the optimal, which worsens the allocative inefficiency. This shows up in the aggregate fall in TFP.

The model performs well in predicting the behavior of investment to GDP ratio. The third graph of Figure 3.3 shows the model underpredicts a recovery of the investment to GDP ratio. It changes from 20 percent to about 15 percent both in the model and in the data. It recovers at a faster rate in the data, back to 20 percent in two years and continues to show an increasing trend. In the model, however, it takes one more year to return to normal and stagnates after that.

In addition, the model predicts a current account reversal, as shown in the fourth graph of Figure 3.3. The model overpredicts the magnitude of the change. As interest rate increases, the current account to GDP ratio increased to about 10 percent in 1995 and almost 30 percent in the following year in the model, as compared to about 5 percent in the data. After the shock, as interest rate returns back to the pre-shock level, the trade deficit worsens at a faster rate in the model.

The model also estimates that bank loans to the private sector decrease after the interest rate hike, although the magnitude of the change is larger in the model. The intuition is that after the world interest rate shock, it is harder for the bank to issue bonds in the international capital market, therefore undermines its ability to lend to domestic firms. Taking the steady state in 1994 as the base, the data shows that the bank loans decrease to 88 percent in both 1995 and 1996, while the model predicts that it decreases to about 73 percent in 1995 and 60 percent in 1996. Both model and data show that the bank loans to private sector does not change much after that.

3.5 Conclusion

In this paper, I investigate the role of a banking sector in a small open economy during sudden stop episodes. First, I document the key facts in the data about the importance of the banking sector in emerging countries. I find that a significant portion of the domestic credits is provided by the banking sector. For example, in Korea, about 60% of domestic credits was provided by banks in the 1990s, while in Mexico this number was over 40%. Moreover, a positive contemporaneous correlation between GDP and Bank loans is seen in both Mexico and Argentina. Previous theories have largely focused on the impact of an exogenous change in domestic interest rate on the economy (e.g., Neumeyer and Perri (2005)). Little attention has been drawn upon the impact of a change in the world interest rate on the domestic interest rate and credit supply through banks' intermediation. In this paper, I explore the role of banks' intermediation in exacerbating the allocative inefficiency.

In particular, I build a small open economy model in which banks are the only domestic agents with access to international capital markets. During sudden stops, a shock to the world interest rate will decrease banks' credit supply and raise domestic interest rate on loans. Firms, with working capital financing needs, will experience an increase in the cost of production. This worsens the misallocation and generates an endogenous fall in TFP and output. The model is then calibrated to analyze the sudden stop in Mexico in 1995 and subjected to an unexpected shock to the world interest rate. The model generates a fall in output and can explain more than half of the fall in TFP. The model also performs well in predicting the behavior of investment, bank loans, and a current account reversal.

References

ALBOUY, D. (2008): "Are Big Cities Really Bad Places to Live? Improving Quality-Of-Life Estimates Across Cities," NBER Working Papers 14472, National Bureau of Economic Research, Inc.

——— (2009): "The Unequal Geographic Burden of Federal Taxation," *Journal of Political Economy*, 117(41), 635–67.

ALONSO, W. (1964): *Location and Land Use: Toward a General Theory of Land Rent.* Harvard University Press.

ANAS, A., R. ARNOTT, AND K. A. SMALL (1998): "Urban Spatial Structure," *Journal of Economic Literature*, 36(3), 1426–1464.

——— (2000): "The Panexponential Monocentric City Model," *Journal of Urban Economics*, 47, 165–179.

ATKIN, D., AND D. DONALDSON (2014): "Who's Getting Globalized? The Size and Implications of Intra-national Trade Costs," .

BACOLOD, M., B. S. BLUM, AND W. C. STRANGE (2009): "Skills in the City," *Journal of Urban Economics*, 65(2), 136–153.

BAUM-SNOW, N., AND R. PAVAN (2012): "Understanding the City Size Wage Gap," *Review of Economic Studies*, 79(1), 88–127.

BECK, T., A. DEMIRGUC-KUNT, AND R. LEVINE (2000): "A New Database on Financial Development and Structure," *World Bank Economic Review*, 14, 597–605.

Behrens, K., G. Duranton, and F. Robert-Nicoud (2014): "Productive cities: Sorting, Selection and Agglomeration," *Journal of Political Economy*, 122(3), 507–553.

Behrens, K., and F. Robert-Nicoud (2014): "Survival of the Fittest in Cities: Agglomeration, Selection, and Inequality," *The Economic Journal*, 124(581), 1371–1400.

Black, D., and J. V. Henderson (2003): "Urban Evolution in the USA," *Journal of Economic Geography*, 3, 343–372.

Busso, M., J. Gregory, and P. Kline (2013): "Assessing the Incidence and Efficiency of a Prominent Place Based Policy," *American Economic Review*, 103(2), 897–947.

Calvo, G., L. Leiderman, and C. Reinhart (1993): "Capital inflows and real exchange rate appreciation in latin america: The role of external factors.," *IMF Staff Papers*, 40(1), 108–151.

——— (1996): "Inflows of capital to developing countries in the 1990s.," *The Jorunal of Economic Perspectives*, 10(2), 123–139.

Calvo, G., and E. G. Mendoza (2000): "Rational contagion and the globalization of security markets.," *Journal of International Economics*, 51, 79–113.

Carrillo, P. E., D. W. Early, and E. O. Olsen (2014): "A Panel of Interarea Price Indices for All Areas in the United States 1982-2012," .

Cecchetti, S. G., N. C. Mark, and R. J. Sonora (2002): "Price Index Convergence among United States Cities," *International Economic Review*, 43(4), 1081–1099.

Chatterjee, S., and B. Eyigungor (2013): "Do Supply Restrictions Raise the Value of Urban Land? The (Neglected) Role of Production Externalities," Working Paper 13-37, Federal Reserve Bank of Philadelphia.

Chevalier, J. A. (1995): "Capital structure and product-market competition: Empirical evidence from the supermarket industry," *The American Economic Review*, 85(3), 415–435.

Combes, P.-P., G. Duranton, and L. Gobillon (2008): "Spatial Wage Disparities: Sorting Matters!," *Journal of Urban Economics*, 63(2), 723–742.

Combes, P.-P., G. Duranton, L. Gobillon, D. Puga, and S. Roux (2012): "The Productivity Advantages of Large Cities: Distinguishing Agglomeration from Firm selection," *Econometrica*, 80(6), 2543–2594.

Combes, P.-P., G. Duranton, L. Gobillon, and S. Roux (2012): "Sorting and Local Wage and Skill Distributions in France," *Regional Science and Urban Economics*, 42(6), 913–930.

Combes, P.-P., T. Mayer, and J.-F. Thisse (2008): *Economic Geography.* Princeton University Press.

Crucini, M. J., and M. Shintani (2008): "Persistence in law of one price deviations: Evidence from micro-data," *Journal of Monetary Economics*, 55(3), 629–644.

Dahl, G. B. (2002): "Mobility and the Return to Education: Testing a Roy Model with Multiple Markets," *Econometrica*, 70(6), 2367–2420.

Davis, D. R., and J. I. Dingel (2012): "A Spatial Knowledge Economy," NBER Working Papers 18188, National Bureau of Economic Research, Inc.

——— (2013): "The Comparative Advantage of Cities," Manuscript, Economics Department, Columbia University.

Davis, M. A., and F. Ortalo-Magne (2011): "Household Expenditures, Wages, Rents," *Review of Economic Dynamics*, 14(2), 248–261.

Diamond, R. (2013): "The Determinants and Welfare Implications of US Workers' Diverging Location Choices by Skill: 1980-2000," Manuscript, Department of Economics, Stanford University.

Diaz-Gimenez, J., E. Prescott, T. Fitzgerald, and F. Alvarez (1992): "Banking in Computable General Equilibrium Economies.," *Journal of Economic Dynamics and Control*, 16, 533–559.

DIXIT, A. K., AND J. E. STIGLITZ (1977): "Monopolistic Competition and Optimum Product Diversity," *American Economic Review*, 67(3), 297–308.

DORNBUSCH, R., S. FISCHER, AND P. A. SAMUELSON (1977): "Comparative Advantage, Trade, and Payments in a Ricardian Model with a Continuum of Goods," *American Economic Review*, 67, 823–839.

DORNBUSCH, R., S. FISCHER, AND P. A. SAMUELSON (1980): "Heckscher-Ohlin Trade Theory with a Continuum of Goods," *The Quarterly Journal of Economics*, 95(2), 203–224.

DUMOND, J. M., B. T. HIRSCH, AND D. A. MACPHERSON (1999): "Wage Differentials Across Labor Markets and Workers: Does Cost of Living Matter?," *Economic Inquiry*, 37(4), 577–598.

DURANTON, G., AND D. PUGA (2000): "Diversity and Specialisation in Cities: Why, Where and When Does it Matter?," *Urban Studies*, 37, 533–555.

——— (2004): "Micro-foundations of Urban Agglomeration Economies," in *Handbook of Regional and Urban Economics*, ed. by J. V. Henderson, and J.-F. Thisse, pp. 2063–2117. North-Holland, Amsterdam.

EECKHOUT, J., R. PINHEIRO, AND K. SCHMIDHEINY (2014): "Spatial Sorting," *Journal of Political Economy*, 122(3), 554–620.

ENGEL, C., AND J. H. ROGERS (1997): "Violating the Law of One Price: Should We Make a Federal Case Out of It?," unpublished manuscript, University of Washington.

ETHIER, W. J. (1982a): "Decreasing Costs in International Trade and Frank Graham's Argument for Protection," *Econometrica*, 50, 1243–1268.

——— (1982b): "National and International Returns to Scale in the Modern Theory of International Trade," *American Economic Review*, 72(3), 389–405.

FUJITA, M. (1988): "A Monopolistic Competition Model of Spatial Agglomeration," *Regional Science and Urban Economics*, 18, 87–124.

——— (1989): *Urban Economic Theory*. Cambridge University Press.

Fujita, M., P. Krugman, and A. J. Venables (1999): *The Spatial Economy.* MIT Press.

Fujita, M., and J.-F. Thisse (2013): *Economics of Agglomeration: Cities, Industrial Location, and Globalization.* Cambridge University Press.

Gaubert, C. (2014): “Firm Sorting and Agglomeration,” Manuscript, Department of Economics, Princeton University.

Gibbons, S., H. G. Overman, and P. Pelkonen (2010): “Wage Disparities in Britain: People or Place?,” Discussion Paper 0060, SERC.

Glaeser, E. L. (2008): *Cities, Agglomeration, and Spatial Equilibrium.* Oxford University Press.

Glaeser, E. L., and J. D. Gottlieb (2008): “The Economics of Place-Making Policies,” *Brookings Papers on Economic Activity*, 2, 155–239.

Glaeser, E. L., and J. Gyourko (2005): “Urban Decline and Durable Housing,” *Journal of Political Economy*, 113, 345–375.

Glaeser, E. L., J. Gyourko, and R. Saks (2005): “Why is Manhattan So Expensive? Regulation and the Rise in House Prices,” *Journal of Law and Economics*, 48(2), 331–370.

——— (2006): “Urban Growth and Housing Supply,” *Journal of Economic Geography*, 6, 71–89.

Glaeser, E. L., and M. G. Resseger (2010): “The Complementarity between Cities and Skills,” *Journal of Regional Science*, 50(1), 221–244.

Glaeser, E. L., and A. Saiz (2004): “The Rise of the Skilled City,” *Brookings-Wharton Papers on Urban Affairs*, 5, 47–94.

Glaeser, E. L., and K. Tobio (2008): “The Rise of the Sunbelt,” *Southern Economic Journal*, 74(3), 610–643.

Greenwood, M. J. (1997): "Internal Migration in Developed Countries," in *Handbook of Population and Family Economics*, ed. by M. R. Rosenzweig, and O. Stark, pp. 647–720. Elsevier.

Gurley, J., and E. Shaw (1960): *Money in the Theory of Finance*. Brooking Institution, Washington.

Gyourko, J., A. Saiz, and A. A. Summers (2008): "A New Measure of the Local Regulatory Environment for Housing Markets: The Wharton Residential Land Use Regulatory Index," *Urban Studies*, 45(3), 693–729.

Handbury, J. (2013): "Are Poor Cities Cheap for Everyone? Non-Homotheticity and the Cost of Living Across U.S. Cities," .

Handbury, J., and D. E. Weinstein (2014): "Goods Prices and Availability in Cities," *Review of Economic Studies*.

Helpman, E. (1986): "Increasing Returns, Imperfect Markets and Trade Theory," in *Handbook of International Economics*, ed. by R. Jones, and P. Kenen.

——— (1998): "The Size of Regions," in *Topics in Public Economics*, ed. by I. Z. D. Pines, and E. Sadka, pp. 33–54. Cambridge University Press.

Henderson, J. V. (1974): "The Sizes and Types of Cities," *American Economic Review*, 64(4), 640–656.

Holmes, T. J., and J. J. Stevens (2004): "Geographic Concentration and Establishment Size: Analysis in an Alternative Economic Geography Model," *Journal of Economic Geography*, 4(3), 227–250.

Hsieh, C., and E. Moretti (2014): "Growth in Cities and Countries," .

Karadi, P., and M. Koren (2008): "A Spatial Explanation for the Balassa-Samuelson Effect," *CeFiG Working Papers*, 4.

Kehoe, T., and K. Ruhl (2009): "Sudden Stops, Sectoral Reallocations, and the Real Exchange Rate," *Journal of Development Economics*, 89, 235–249.

Kline, P., and E. Moretti (2013): "Local Economic Development, Agglomeration Economies, and the Big Push: 100 Years of Evidence from the Tennessee Valley Authority," .

Krugman, P. (1991): "Increasing Returns and Economic Geography," *Journal of Political Economy*, 99(3), 483–499.

Krugman, P., and A. J. Venables (1995): "Globalization and Inequality of Nations," *Quarterly Journal of Economics*, 110(4), 857–880.

Lucas, R. E. (1978): "On the Size Distribution of Business Firms," *The Bell Journal of Economics*, 9(2), 508–523.

Lucas, R. E., and E. Rossi-Hansberg (2002): "On the Internal Structure of Cities," *Econometrica*, 70(4), 1445–1476.

Matsuyama, K. (1996): "Why Are There Rich and Poor Countries?: Symmetry-breaking in the World Economy," *Journal of the Japanese and International Economies*, 10, 419–439.

——— (2013): "Endogenous Ranking and Equilibrium Lorenz Curve across (ex ante) Identical Countries," *Econometrica*, 81, 2009–2031.

Mayer, T., F. Mayneris, and L. Py (2012): "The Impact of Urban Enterprise Zones on Establishments' Location Decisions: Evidence from French ZFUs," .

Melitz, M. J. (2003): "The Impact of Trade on Intra-industry Reallocations and Aggregate Industry Productivity," *Econometrica*, 71(6), 1695–1725.

Mendoza, E. G. (2010): "Sudden Stops, Financial Crises and Leverage," *American Economic Review*, 100(5), 1941–1966.

Mendoza, E. G., and V. Z. Yue (2008): "A Solution to the Default Risk-Business Cycle Disconnect," International Finance Discussion Papers, Board of Governors of the Federal Reserve System.

Mills, E. S. (1967): "An Aggregative Model of Resource Allocation in a Metropolitan Area," *The American Economic Review*, 57(2), 197–210.

——— (1972): *Studies in the Structure of the Urban Economy*. The Johns Hopkins Press, Baltimore.

Molloy, R., C. L. Smith, and A. Wozniak (2011): "Internal Migration in the United States," *Journal of Economic Perspectives*, 25(3), 173–196.

Moretti, E. (2004a): "Human Capital Externalities in Cities," in *Handbook of Regional and Urban Economics*, ed. by J. V. Henderson, and J.-F. Thisse. North-Holland, Amsterdam.

——— (2004b): "Workers' Education, Spillovers, and Productivity: Evidence from Plant-level Production Functions," *American Economic Review*, 94, 656–690.

——— (2012): *The New Geography of Jobs*. Houghton Miin Harcourt.

——— (2013): "Real Wage Inequality," *American Economic Journal: Applied Economics*, 5(1), 65–103.

Muth, R. F. (1969): *Cities and Housing: The Spatial Pattern of Urban Residential Land Use*. University of Chicago Press, Chicago.

Neumeyer, P., and F. Perri (2005): "Business Cycles in Emerging Economies: the Role of Interest Rates," *Journal of Monetary Economics*, 52(2), 345–380.

Ottaviano, G. I., T. Tabuchi, and J.-F. Thisse (2002): "Agglomeration and Trade Revisited," *International Economic Review*, 43(2), 409–435.

Oviedo, P. (2003): "Capital Flows and Financial Intermediation in a Small Open Economy: Business Cycles with Neoclassical Banks," .

——— (2005): "World Interest Rate, Business Cycles, and Financial Intermediation in Small Open Economies," .

Parsley, D. C., and S.-J. Wei (1996): "Convergence to the Law of One Price Without Trade Barriers or Currency Fluctuations," *The Quarterly Journal of Economics*, 111(4), 1211–1236.

Pratap, S., and C. Urrutia (2012): “Financial frictions and total factor productivity: Accounting for the real effects of financial crises,” *Review of Economic Dynamics*, 15, 336–358.

Rivera-Batiz, F. L. (1988): “Increasing Returns, Monopolistic Competition, and Agglomeration Economies in Consumption and Production,” *Regional Science and Urban Economics*, 18, 125–153.

Roback, J. (1982): “Wages, Rents, and the Quality of Life,” *Journal of Political Economy*, 90, 1257–1278.

——— (1988): “Wages, Rents, and Amenities: Differences among Workers and Regions,” *Economic Inquiry*, 26, 23–41.

Rosen, S. (1979): “Wages-Based Indexes of Urban Quality of Life,” in *Current Issues in Urban Economics*, ed. by P. Mieszkowski, and M. Straszheim. Johns Hopkins University Press, Baltimore.

Rosenthal, S. S., and W. C. Strange (2004): “Evidence on the Nature and Sources of Agglomeration Economies,” in *Handbook of Regional and Urban Economics*, ed. by J. V. Henderson, and J.-F. Thisse, pp. 2119–2171. North-Holland, Amsterdam.

Ruggles, S., J. T. Alexander, K. Genadek, R. Goeken, M. B. Schroeder, and M. Sobek (2010): *Integrated Public Use Microdata Series: Version 5.0 [Machine-readable database]*University of Minnesota, Minneapolis.

Saiz, A. (2010): “The Geographic Determinants of Housing Supply,” *Quarterly Journal of Economics*, 125(3), 1253–1296.

Saks, R. E. (2008): “Job Creation and Housing Construction: Constraints on Metropolitan Area Employment Growth,” *Journal of Urban Economics*, 64(1), 178–195.

Sharif, I. (2010): “Bank Credit and Economic Activity,” *Journal of Business and Policy Research*, 5(1), 179–188.

Story, L. (2012): “As Companies Seek Tax Deals, Governments Pay High Price,” .

SUEDEKUM, J. (2006): “Agglomeration and Regional Costs of Living,” *Journal of Regional Science*, 46(3), 529–543.

TABUCHI, T. (2001): “On Interregional Price Differentials,” *The Japanese Economic Review*, 52(1), 104–115.

URIBE, M., AND V. Z. YUE (2006): “Country Spreads and Emerging Countries: Who Drives Whom?,” *Journal of International Economics*, 69, 6–36.

WHEELER, C. H. (2001): “Search, Sorting, and Urban Agglomeration,” *Journal of Labor Economics*, 19(4), 879–899.

Appendix A

Chapter 1

A1. Theory

A1.1 Proofs

Proposition 1

Proof. Using equations (1.2.12), (1.3.1) and (1.3.2), we can write a single equation which determines φ^* :

$$\Gamma^A \varphi^{*\frac{1}{\varepsilon}} \int_{\underline{\varphi}}^{\varphi^*} dF(\varphi) = \left(\frac{1+\varepsilon}{\varepsilon} - \Gamma^A \right) \int_{\varphi^*}^{\infty} \varphi^{\frac{1}{\varepsilon}} d\varphi.$$

The left-hand side of this equation is monotonically increasing in φ^*, starting from 0 and strictly positive when $\varphi^* \to +\infty$. The right-hand side is monotonically decreasing in φ^* and equal to 0 when $\varphi^* \to +\infty$. By continuity, there exists a unique equilibrium. Also, this equation shows that φ^* does not depend on city population. □

Lemma 1

Proof. From (1.2.12), we have

$$\frac{\varphi_1^*}{\varphi_2^*} = \left(\frac{\Phi_1}{\Phi_2} \right) \left(\frac{w_1/\Gamma_1}{w_2/\Gamma_2} \right)^{\varepsilon}.$$

Equation (1.3.7), i.e., the condition that a team leader with productivity φ^{**} is indifferent between locating in either city, together with the team leader's income in (1.2.10), give us

$$\left(\frac{\Phi_2}{\Phi_1}\right)^{\frac{1}{\varepsilon}}\left(\frac{\Gamma_1}{\Gamma_2}\right) = \left(\frac{R_1}{R_2}\right)^{1-\alpha}.$$

Using this equation and (1.3.6) we will have $\varphi_1^* = \varphi_2^*$. □

Lemma 2

Proof. Lemma 1 states that $\varphi_1^* = \varphi_2^*$, i.e.,

$$\Phi_1\left(\frac{w_1}{\Gamma_1}\right)^{\varepsilon} = \Phi_2\left(\frac{w_2}{\Gamma_2}\right)^{\varepsilon}.$$

That is,

$$\left(\frac{\Phi_1}{\Phi_2}\right)^{\frac{1}{\varepsilon}}\frac{\Gamma_2}{\Gamma_1} = \frac{w_2}{w_1}.$$

From (1.2.10),

$$\frac{\pi_2(\varphi)}{\pi_1(\varphi)} = \left(\frac{\Phi_1}{\Phi_2}\right)^{\frac{1}{\varepsilon}}\frac{\Gamma_2}{\Gamma_1} = \frac{w_2}{w_1}.$$

From (1.3.5), we know that $w_2 > w_1$, so $\pi_2(\varphi) > \pi_1(\varphi)$ for all φ. □

Proposition 2

Proof. From (1.3.5) and (1.3.6), we know that both w_j and R_j depend on aggregate productivity ratio, not individual team leader's location choice. Individual team leaders take both wage rates and housing prices as given. Now consider a team leader with $\varphi \geq \varphi^*$. Her income gain by locating to City 2 is

$$\Delta\pi(\varphi) = \pi_2(\varphi) - \pi_1(\varphi)$$

$$= \frac{\alpha\varepsilon}{1+\varepsilon}\varphi^{\frac{1}{\varepsilon}}Y\left[\Phi_2^{-\frac{1}{\varepsilon}}\Gamma_2 - \Phi_1^{-\frac{1}{\varepsilon}}\Gamma_1\right] > 0.$$

The second equality comes from equation (1.2.10). This income gain is positive, as stated in Lemma 2.

$$\frac{\partial\Delta\pi(\varphi)}{\partial\varphi} = \frac{\alpha}{1+\varepsilon}\varphi^{-1+\frac{1}{\varepsilon}}Y\left[\Phi_2^{-\frac{1}{\varepsilon}}\Gamma_2 - \Phi_1^{-\frac{1}{\varepsilon}}\Gamma_1\right] > 0$$

As φ increases, the income gain is larger by locating to City 2. Since φ^{**} is the productivity threshold at which the income gain exactly compensates for the high housing price, any $\varphi > \varphi^{**}$ will give the team leader more income gain compared to the housing price difference. Therefore, team leaders with $\varphi \geq \varphi^{**}$ sort into City 2 and team leaders with φ such that $\varphi^{*} \leq \varphi < \varphi^{**}$ sort into City 1. □

A1.2 The Baseline Model: the Analytical Solution of the Asymmetric Equilibrium

In this section, I show that the asymmetric equilibrium in which City 2 has more skill-intensive varieties of components can be summarized as a fixed-point problem of S.

Given the Pareto distribution of the productivity, $F(\varphi)$, and the two cutoffs, φ^{*} and φ^{**}, the number of team leaders in each city, $L_{E,j}$, and the aggregate productivity in each city, Φ_j, can be written as functions of the two cutoffs, φ^{*} and φ^{**}.

$$L_{E,1} = L\underline{\varphi}^{\delta}\left(\varphi^{*-\delta} - \varphi^{**-\delta}\right),$$

$$L_{E,2} = L\left(\frac{\underline{\varphi}}{\varphi^{**}}\right)^{\delta},$$

$$\Phi_1 = \left[\frac{\delta\underline{\varphi}^{\delta}L}{\frac{1}{\varepsilon}-\delta}\left(\varphi^{**\frac{1}{\varepsilon}-\delta} - \varphi^{*\frac{1}{\varepsilon}-\delta}\right)\right]^{\varepsilon},$$

$$\Phi_2 = \left(\frac{\delta\underline{\varphi}^{\delta}L}{\delta-\frac{1}{\varepsilon}}\varphi^{**\frac{1}{\varepsilon}-\delta}\right)^{\varepsilon},$$

where I assume $\delta > \frac{1}{\varepsilon}$.

Now consider the labor market clearing conditions. Labor in the whole economy is supplied by all individuals with productivity less than φ^{*}. Let L_W be the total number of workers in both cities, i.e., $L_W = F(\varphi^{*}) = 1 - \left(\frac{\underline{\varphi}}{\varphi^{*}}\right)^{\delta}$. Then labor supply is equal to $w_j\lambda_j L_W$ in each city, where $\lambda_j \in (0,1)$ denotes the share of city j in workers. Labor demand comes from two sources. Each team leader with productivity φ demands $l(\varphi) = \frac{x(\varphi)}{\varphi}$ units of labor. In addition, final goods sectors in City 1 spend $\alpha(S-\Gamma_1)Y$

on labor. Therefore, the labor market clearing condition in City 1 becomes

$$\alpha\left(S-\Gamma_1\right)Y+w_1L\int\frac{x\left(\varphi\right)}{\varphi}dF\left(\varphi\right)=w_1\lambda_1L_W.$$

Using (1.2.8) and (1.2.9), this equation can be simplified to

$$\alpha Y\left(S-\Gamma_1+\frac{\Gamma_1}{1+\varepsilon}\right)=w_1\lambda_1L_W.$$

Likewise, the labor market clearing condition in City 2 can be simplified to

$$\alpha Y\left(1-S-\Gamma_2+\frac{\Gamma_2}{1+\varepsilon}\right)=w_2\lambda_2L_W,$$

if we define $\Phi_1\equiv\left(L\int_{\varphi^*}^{\varphi^{**}}\varphi^{\frac{1}{\varepsilon}}dF\left(\varphi\right)\right)^{\varepsilon}$ and $\Phi_2\equiv\left(L\int_{\varphi^{**}}^{\infty}\varphi^{\frac{1}{\varepsilon}}dF\left(\varphi\right)\right)^{\varepsilon}$. The labor market clearing conditions, together with the free migration of workers, i.e., (1.3.6), give the wage rates as:

$$w_1=\frac{\alpha Y\left(S-\Gamma_1+\frac{\Gamma_1}{1+\varepsilon}\right)}{\lambda_1L_W},$$

$$w_2=w_1\left(\frac{R_2}{R_1}\right)^{1-\alpha},$$

$$\lambda_1=\frac{S-\Gamma_1+\frac{\Gamma_1}{1+\varepsilon}}{S-\Gamma_1+\frac{\Gamma_1}{1+\varepsilon}+\left(1-S-\Gamma_2+\frac{\Gamma_2}{1+\varepsilon}\right)\left(\frac{R_1}{R_2}\right)^{1-\alpha}},\qquad \lambda_2=1-\lambda_1.$$

Here wage rates are expressed in terms of Γ_j, L_W, and the land rents ratio R_2/R_1. Since Γ_j is a function of S and L_W is a function of φ^*, wage rates are functions of S , φ^* and land rents ratio. The next step is to look at the land market clearing condition. Supply of land is fixed at 1 in each city, while demand for land is from individuals.

$$\int h_j\left(\varphi\right)d\varphi=1$$

is the simple land market clearing condition for each city j. According to the Cobb-Douglas preference, the land market clearing condition can be written as

$$R_j=\left(1-\alpha\right)Y_j,$$

where Y_j is city j's income excluding land rents:

$$Y_j = L \int \pi_j(\varphi)\, dF(\varphi) + w_j \lambda_j L_W.$$

Using (1.2.10), I can simplify this equation to

$$Y_j = \frac{\alpha\varepsilon}{1+\varepsilon} Y \Gamma_j + w_j \lambda_j L_W.$$

Using the labor market clearing condition above, I can further rewrite this as

$$Y_1 = \alpha Y S,$$

and

$$Y_2 = \alpha Y (1 - S).$$

Therefore, the land rents ratio is

$$\frac{R_1}{R_2} = \frac{Y_1}{Y_2} = \frac{S}{1-S}.$$

Given this, the wage rates w_j and the spatial distribution of workers λ_j are now functions of S and φ^*.

Now I show that the two productivity cutoffs φ^* and φ^{**} are functions of S. The first condition I will use is (1.2.12), which states that an individual with productivity φ^* is indifferent between being a team leader and a worker:

$$\varphi^* = \Phi_1 \left(\frac{1+\varepsilon}{\alpha\varepsilon} \frac{w_1}{Y\Gamma_1} \right)^{\varepsilon}.$$

Using the expressions for the aggregate productivity and the labor market clearing condition, I have

$$\varphi^* = \left[\frac{\delta \underline{\varphi}^{\delta} L}{\frac{1}{\varepsilon} - \delta} \left(\varphi^{**\frac{1}{\varepsilon}-\delta} - \varphi^{*\frac{1}{\varepsilon}-\delta} \right) \right]^{\varepsilon} \left[\frac{1+\varepsilon}{\varepsilon} \frac{S - \Gamma_1 + \frac{\Gamma_1}{1+\varepsilon}}{\Gamma_1 \lambda_1 L \left(1 - \left(\frac{\underline{\varphi}}{\varphi^*} \right)^{\delta} \right)} \right]^{\varepsilon}.$$

Γ_j and λ_j are functions of φ^*, φ^{**}, and S. Therefore, for a given S, this is one condition that gives the relationship between φ^* and φ^{**}. The second condition that I will use is equation (1.3.7), which states that a team leader with productivity φ^{**} is indifferent between locating in City 1 and City 2:

$$\frac{\pi_1(\varphi^{**})}{\pi_2(\varphi^{**})} = \left(\frac{R_1}{R_2}\right)^{1-\alpha}.$$

And this can be reduced to

$$\left(\frac{\Phi_2}{\Phi_1}\right)^{\frac{1}{\varepsilon}} \frac{\Gamma_1}{\Gamma_2} = \left(\frac{R_1}{R_2}\right)^{1-\alpha}.$$

Plugging in the aggregate productivities into the left side, this equation can be rewritten as

$$\frac{\varphi^{**\frac{1}{\varepsilon}-\delta}}{\varphi^{*\frac{1}{\varepsilon}-\delta} - \varphi^{**\frac{1}{\varepsilon}-\delta}} \frac{\Gamma_1}{\Gamma_2} = \left(\frac{S}{1-S}\right)^{1-\alpha},$$

which adds another condition to the relationship between φ^* and φ^{**} for a given S. Therefore, for a given S, there are two unknowns, φ^* and φ^{**}, and two equations. This system of equations, if solved, implies that φ^* and φ^{**} are obtained as functions of S.

In the above analysis, I take S as given. Now, I discuss the condition that can pin down the value of S. The condition that determines the value of S is the comparative advantage condition for sector S, which states that the unit production costs of final good S in both cities are equalized:

$$\frac{C_1(S)}{C_2(S)} = \left(\frac{w_1}{w_2}\right)\left(\frac{\Phi_1}{\Phi_2}\right)^{-\gamma(S)} = 1,$$

which can be rewritten as

$$\left(\frac{S}{1-S}\right)^{1-\alpha} \left(\frac{\varphi^{*\frac{1}{\varepsilon}-\delta} - \varphi^{**\frac{1}{\varepsilon}-\delta}}{\varphi^{**\frac{1}{\varepsilon}-\delta}}\right)^{-\gamma(S)\varepsilon} = 1.$$

Since both φ^* and φ^{**} are functions of S, this is a single equation that determines the value of S. Hence, the equilibrium can be summarized as a fixed-point problem of S.

A2. Data and Estimations

A2.1 Data Description

Data Sources

The data on individuals' education, wages, demographics, and industries in which they are employed come from two sources. One source is from the public-use samples of the decennial U.S. census and the annual American Community Survey (ACS) made available by IPUMS-USA (Ruggles, Alexander, Genadek, Goeken, Schroeder, and Sobek, 2010). I use the 2010 ACS sample. This sample is used to calculate the skill composition of each industry and serves as a robustness check for the skill distribution across cities. The other source of data comes from the Current Population Survey (CPS), a joint effort between the Bureau of Labor Statistics (BLS) and the Census Bureau. This sample is used primarily to analyze the spatial skill distribution. The housing price data come from the price indices constructed by Carrillo, Early, and Olsen (2014). They post panels of annual price indices for housing services, other goods and services, and all goods and services that cover the period 1982 through 2012. These price indices are available for public use and are updated yearly. The data on sectoral employment are taken from the 2010 County Business Patterns published by the U.S. Census Bureau.

Skill Distribution

I use the CPS data to calculate the fraction of highly skilled workers in each city. I use the 2010 merged outgoing rotation groups (MORG) as provided by the National Bureau of Economic Research (NBER). The MORG are extracts of the basic monthly data of CPS during the household's fourth and eighth month in the survey, when usual weekly hours/earnings are asked. I exclude those observations with missing values in education and income variables. I study individuals whose highest education is some college (including associate degrees), a bachelor's degree, a master's degree, a professional degree or a Ph.D. degree. Only those full-time, full-year employees are included in the sample, defined as individuals who work at least 40 weeks during the year and usually work at least 35 hours per week.

Housing Prices

The housing price indices are taken from Carrillo, Early, and Olsen (2014). Their price index panels are constructed by first creating cross-section price indices for the year 2000 in 380 areas (including metro and non-metro areas). Then they use the BLS time-series price indices for particular metropolitan areas and other urban areas grouped according to their region and size to create the panel of prices. I use the 2010 data. Their housing price indices are based on data on the gross rent and numerous housing, neighborhood, and location characteristics of about 170,000 units throughout the United States.

Sectoral Employment

County Business Patterns (CBP) provides annual statistics for businesses with paid employees within the U.S., Puerto Rico, and Island Areas (Guam, American Samoa, the Commonwealth of the Northern Mariana Islands, and the U.S. Virgin Islands) at a detailed geography and industry level. CBP covers most NAICS industries excluding crop and animal production; rail transportation; National Postal Service; pension, health, welfare, and vacation funds; trusts, estates, and agency accounts; private households; and public administration. CBP also excludes most establishments reporting government employees. The 2010 CBP from the U.S. Census Bureau contains employment data for 6-digit NAICS industries across 348 MSAs. I use 21 three-digit NAICS industries.

Skill Compositions by Industries

I use the 2010 ACS sample to calculate the skill composition of industries. I study full-time, full-year employees, defined as individuals who work at least 40 weeks during the year and usually work at least 35 hours per week. I consider U.S. born workers with age between 25 and 55. I weight the sample using the person weight to ensure that the sample is representative. The industries in which individuals are employed are in the variable “indnaics”. The “indnaics” codes are three or four digit codes, some of which include alphabetic characters. I extract the first three digit and match them with standard NAICS codes. For each industry, I calculate the percent of college graduates, defined as those with 4 years of college or more (i.e., variable “educ” is greater than or equals 10).

Per Capita Income

The data for per capita income in MSAs are taken from the Bureau of Economic Analysis (BEA). According to the reports, "per capita personal income is calculated as the personal income of residents of a given area divided by the resident population of the area." In computing per capita personal income, BEA uses the Census Bureau's annual mid-year population estimates. Personal income is defined as the income received by all persons from all sources. "It is the sum of net earnings by place of residence, rental income of persons, personal dividend income, personal interest income, and personal current transfer receipts. Personal income is measured before the deduction of personal income taxes and other personal taxes and is reported in current dollars (no adjustment is made for price changes)."

A2.2 Estimations

Table A.1: Relationship of Housing Prices and Industrial Shares across Cities

Manufacturing Industries	Coefficient	Manufacturing Industries	Coefficient
Food	-1.810***	Chemical	1.458*
	(0.390)		(0.722)
Beverage and Tobacco Product	-0.867	Plastic and Rubber Products	-1.433***
	(0.782)		(0.341)
Textile Mills	-4.457**	Nonmetallic Mineral Product	-1.198***
	(1.266)		(0.259)
Textile Product Mills	-0.888	Primary Metal	-4.065***
	(0.576)		(0.619)
Apparel	-0.859	Fabricated Metal	-1.616***
	(0.585)		(0.268)
Leather and Allied Product	-2.939	Machinery	-1.620***
	(1.400)		(0.361)
Wood Product	-2.459***	Computer and Electronic Product	2.803***
	(0.407)		(0.519)
Paper	-2.732***	Electrical Equip., App. & Comp.	-1.924***
	(0.502)		(0.483)
Printing and Support Activities	0.456	Transportation Equipment	-2.168***
	(0.278)		(0.522)
Petroleum and Coal Products	-4.684**	Furniture	-0.638
	(1.665)		(0.400)
		Miscellaneous	0.622
			(0.317)
Observations	2612	Observations	2612
R-squared	0.293	R-squared	0.293
Industry Fixed Effects	Yes	Industry Fixed Effects	Yes

Standard errors in parentheses

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

A3: Cross-city Price Differences

Throughout this paper, I use the housing price as an approximation for urban cost. Large cities have higher housing prices. What about prices of other goods? Can housing price differences explain the price differences of all goods? One explanatory variable on price differences across cities is population, which yields a common agglomerating force across many New Economic Geography (NEG) models. While standard price indices show a positive correlation between average prices and city sizes, however, as shown in Handbury and Weinstein (2014), this correlation almost entirely disappears when they compare transaction prices of identical products purchased in the same stores across cities. They find that price level for food products actually falls with city size.

To test whether price differences across cities are mainly explained by housing price differences, I use the ACCRA Cost of Living Index produced by The Council for Community and Economic Research. The ACCRA Cost of Living Index provides a useful and reasonably accurate measure of cost of living differences between urban areas. Items on which the Index is based have been carefully chosen to reflect the different categories of consumer expenditures. Using the detailed component data for 54 individual goods and services collected in the 209 U.S. cities in 2010, I find that a one log-unit rise in city size is associated with a 3.4% increase in non-tradable price index but only a 1.2% increase in tradable price index. One possible explanation is that rents are high in large cities. Using the housing price index as an approximation for rent, I find that controlling for rent differences across cities, the impact of population on non-tradable price decreases by 56%. On the other hand, adding rent as an explanatory variable in tradable prices makes population not statistically significant.

Therefore, I conclude that the cross-city prices of both tradable and non-tradable goods can be explained by housing price differences. Including the housing price in the regressions significantly reduces the effect of population on prices.

Table A.2: Prices and Metropolitan Characteristics, 2010

	(1)	(2)	(3)	(4)
	log P_T	log P_T	log P_N	log P_N
log MSA population	0.012***	0.005	0.034***	0.015*
	(0.004)	(0.004)	(0.007)	(0.007)
log Housing index		0.089***		0.225***
		(0.018)		(0.035)
Constant	4.445***	4.135***	4.157***	3.373***
	(0.047)	(0.076)	(0.097)	(0.152)
Observations	209	209	209	209
Adjusted R^2	0.048	0.148	0.086	0.231

Standard errors in parentheses

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Appendix B

Chapter 2

Proofs

Lemma 1.

Proof. Rearranging (2.4.6) gives

$$exp\left(\frac{\tau_s - \tau_m}{1-\beta}S_1\right)\int_0^{S_1} rexp\left(-\frac{\tau_s - \kappa\beta}{1-\beta}r\right)dr = \frac{\alpha_2}{\alpha_1}\int_{S_1}^{S_2} rexp\left(-\frac{\tau_m - \kappa\beta}{1-\beta}r\right)dr$$

Given any $S_2 > 0$, since $\tau_s > \tau_m$ and $\kappa\beta < \tau_m < \tau_s$, Left side of the expression above is increasing in S_1. The right side is clearly decreasing in S_1. Furthermore, the left side is 0 for $S_1 = 0$ while the right side is strictly positive, and the left side is strictly positive for $S_1 = S_2$ while the right side is 0. Therefore, for each $S_2 > 0$ there is a unique $S_1 \in (0, S_2)$ that ensures the above expression is satisfied. Observe also that as S_2 goes up and S_1 does not change, the integral on the right side goes up. Since the left side is increasing in S_1, the equilibrium S_1 must be strictly higher. Thus $S_1(S_2)$ is strictly increasing in S_2. □

Lemma 2.

Proof. Given any $S > 0$, since $\kappa < \frac{\tau_m\alpha_3}{1-\beta+\alpha_3\beta}$, left side of (2.4.8) is decreasing in S_2. From Lemma 1, we know $S_1(S_2)$ is increasing in S_2, the right side is increasing in S_2. The rest of the proof is similar to the proof in Lemma 1. □

Proposition 1.

Proof. (i) This is immediate from the expressions of $n_m(0)$ and $n_s(0)$ in (2.4.9) and (2.4.10).

(ii) Notice that $q_F^m(0) = (1-\beta) A_m n_m(0)^\beta$
and $q_H(0) = q_F^m(0) exp\left(-\frac{\alpha_3\tau_m - \alpha_3\kappa\beta - \kappa + \kappa\beta}{\alpha_3(1-\beta)} S_2\right)$.

(iii) It immediately follows from $w(0) = \beta A_m n_m(0)^{\beta-1}$. □

Proposition 2.

Proof. Recall that

$$n_m(0) = \frac{P}{2\pi\left(1+\frac{\alpha_1}{\alpha_2}\right)} \frac{\int_{S_2}^{S} rexp\left(-\frac{\kappa}{\alpha_3}r\right)dr}{exp\left(\frac{\tau_s-\tau_m}{1-\beta}S_1\right)\int_0^{S_1} rexp\left(-\frac{\tau_s-\kappa\beta}{1-\beta}r\right)dr \int_{S_2}^{S} rexp\left(-\frac{\kappa(1-\alpha_3)}{\alpha_3}r\right)dr}.$$

The part $1/\left(exp\left(\frac{\tau_s-\tau_m}{1-\beta}S_1\right)\int_0^{S_1} rexp\left(-\frac{\tau_s-\kappa\beta}{1-\beta}r\right)dr\right)$ is clearly decreasing in S_1 (and S). From Lemma 2 in Chatterjee and Eyigungor (2013), the ratio of integrals

$$\int_{S_2}^{S} rexp\left(-\frac{\kappa}{\alpha_3}r\right)dr \Big/ \int_{S_2}^{S} rexp\left(\left(-\frac{\kappa}{\alpha_3}+\kappa\right)r\right)dr$$

is also decreasing in S. So $n_m(0)$ is decreasing in S. Similarly, $n_s(0)$ is also decreasing in S. Rents $q_F^m(0) = (1-\beta) A_m n_m(0)^\beta$ and $q_H(0) = q_F^m(0) exp\left(-\frac{\alpha_3\tau_m - \alpha_3\kappa\beta - \kappa + \kappa\beta}{\alpha_3(1-\beta)} S_2\right)$ are also decreasing in S. □

Lemma 3.

Proof. Since $q_H(S; A_m, P) = q_H(0) exp\left(-\frac{\kappa}{\alpha_3}S\right)$, the term $exp\left(-\frac{\kappa}{\alpha_3}S\right)$ is decreasing in S and from Proposition 2, holding A_i and P constant, $q_H(0)$ is decreasing in S. So $q_H(S; A_m, P)$ is strictly decreasing in S.

Since $q_F^m(0) = (1-\beta) A_m n_m(0)^\beta$ and $q_H(0) = q_F^m(0) exp\left(-\frac{\alpha_3\tau_m - \alpha_3\kappa\beta - \kappa + \kappa\beta}{\alpha_3(1-\beta)} S_2\right)$, holding fixed S and P, $q_H(0)$ is proportional to A_m and therefore $q_H(S; A_m, P)$ is increasing in A_m. And, holding fixed S and A_m, $q_H(0)$ is increasing in P by Proposition 1. So $q_H(S; A_m, P)$ is increasing in P. □