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Urban Accounting and Welfare†

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We use a simple theory of a system of cities to decompose the determinants of the city size distribution into three main components: efficiency, amenities, and frictions. Higher efficiency and better amenities lead to larger cities but also to greater frictions through congestion and other negative effects of agglomeration. Using data on MSAs in the United States, we estimate these city characteristics. Eliminating variation in any of them leads to large population reallocations, but modest welfare effects. We apply the same methodology to Chinese cities and find welfare effects that are many times larger than those in the US. (*JEL* H71, O18, P25, R11, R23, R41)

Why do people live in particular cities? We can list many reasons, but two are undoubtedly relevant. Agents can enjoy the city or be more productive there. A combination of life amenities and productivity levels determines the size of cities, but the positive effects of these characteristics are capped by the costs and frictions arising from congestion. Depending on city governance and the flexibility of markets, these costs and frictions can be more or less important. These city characteristics are in turn enhanced and amplified by the presence of urban externalities. Understanding the different forces that determine city sizes is crucial for answering a broad set of questions. What is the relative importance of these forces in determining the size distribution of cities? How much would we gain or lose if cities had similar amenities, technology levels, or frictions? How much reallocation would this cause? More generally, what are the welfare implications of the location of agents across cities?

In this paper we provide a simple way of decomposing the characteristics that lead to the size distribution of cities into three main components: efficiency, amenities, and excessive frictions. We use a simple urban theory to calculate these components and to carry out a wide set of counterfactual exercises that provide answers to the questions we asked above. The theory consists of a multi-city model with monocentric cities that produce a single good. Workers decide how much to work and where to live. Efficiency is modeled as TFP, amenities as directly affecting preferences,

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and frictions as the cost of providing urban infrastructure that is paid for with labor taxes. To measure "excessive frictions," we use the concept of a "labor wedge" (see Chari, Kehoe, and McGrattan 2007) and decompose it into the standard congestion effect of city size and the cost of providing city services. A city's "excessive friction" is the relative level of this latter term. We then solve the general equilibrium model with and without externalities.

We first use aggregate data and the corresponding implications of the theory to calibrate all parameters. We then use the structure of the model to identify "excessive frictions" and efficiency levels across cities. Finally, we use the general equilibrium of the model to determine the amenities that make cities be their actual sizes. Therefore, the model matches by construction the size distribution of cities in the United States.[1] To verify externally the results of our identification strategy, which relies on the model's structure and its functional form assumptions, we compute correlations between the estimated amenities and a wide variety of urban attributes that are frequently related to urban amenities, like climate, quality of life, and geography. We also compare our estimates of efficiency to measures of wages and productivity, and our estimates of the labor wedge with a variety of proxies for urban frictions like taxes, government expenditure, unionization, commuting costs, etc. The results match well with the intuitive role that economists usually associate with these urban characteristics. This match is relevant given that our identification relies on the functional forms we use in the theory.

With the triplet of urban characteristics for each city in hand, we perform a variety of counterfactual exercises. The main exercise we focus on consists of eliminating differences across cities in each of the three characteristics (efficiency, amenities, or excessive frictions). Our aim is two-fold. First, we assess the relative importance of the different characteristics in determining the city size distribution. In that sense, the exercise parallels a growth (or business cycle) accounting exercise. Second, in the same way that the business cycle literature is interested in understanding the welfare effects from smoothing shocks across time, we are interested in quantifying the effect of smoothing city characteristics across space. This is relevant for regional policy, which often aims to revamp backward regions by making productive investments (increasing efficiency), improving their attractiveness as a place to live (increasing amenities), or improving local governance (excessive frictions).

For most counterfactuals we find that the changes in utility (and the equivalent changes in consumption) are modest in spite of massive population reallocations. For example, eliminating efficiency differences across cities raises equilibrium utility levels by a mere 1.2 percent, and eliminating amenity differences increases welfare by just 0.2 percent.[2] When we account for externalities, these numbers decline even further. The welfare implications of redistributing agents across cities due to

[1] Our empirical strategy uses data on output, consumption, capital, population, and hours worked but no information on housing prices or land rents. This has the advantage of reducing the data requirements to reproduce the exercise for other countries. However, the implied land values in our model do not necessarily match these prices in each city. In Section II, we verify that the city characteristics we uncover are correlated to average rents in the way our model predicts.

[2] The magnitude of the welfare effects depends on the normalization of the level of utility in the original equilibrium. In terms of consumption these welfare changes are equivalent to, respectively, a 12 percent and a 2 percent increase in consumption. Given the magnitude of the original changes, we view these magnitudes as modest, particularly when compared to the equivalent numbers in the case of China.

switching of any of the fundamental characteristics that account for the actual size distribution are never greater than a couple of percentage points.[3] This is perhaps surprising given that the differences across cities in amenities and efficiency levels can be rather big,[4] and given that the implied population reallocations can be as large as 40 percent. Adding externalities has an important effect on the extensive margin in the counterfactual exercises, with many cities exiting and the urban population settling in the surviving cities. However, these externalities do not increase the welfare effects in the different counterfactual exercises; if anything, the effects are even more modest.

A relevant question is whether the small welfare effects we uncover are inherent to the model or specific to the US. To address this issue, we explore the same counterfactual exercises for the size distribution of cities in China. We find welfare effects that are an order of magnitude larger than in the US. For example, when eliminating efficiency differences across Chinese cities, welfare increases by 47 percent, compared to a corresponding 1.2 percent in the US.

Beginning with Rosen (1979) and Roback (1982), there has been a large literature using price data on rents and wages to infer differences in amenities and productivities across cities. The research strategy derives from the theory of compensating differentials with free mobility of individuals and firms across locations.[5] A more recent literature exploits, instead, the information content on quantity data to infer information on city characteristics (Chatterjee and Carlino 2001; Rappaport 2007; Redding and Sturm 2008). These papers rely on employment or population data to back out location-specific amenity or productivity parameters. In contrast to this previous work, which has at most heterogeneity in amenities and productivity, our paper allows also for heterogeneity in excessive frictions.[6] Furthermore, none of these papers focuses on decomposing the role of the different city characteristics in determining the city size distribution, and neither do they run counterfactual exercises that assess the welfare implications. Our paper is also novel in that it provides a simple methodology to compare urban systems across countries, as we do for the cases of China and the US, where we find enormous differences with large welfare implications.

A few papers have structurally estimated models of city size distributions to run counterfactual exercises. Related to our work is Au and Henderson (2006), who use a model with agglomeration economies and congestion effects to analyze optimal city sizes in China. After estimating their model, they calculate the welfare effects of migration constraints and find that output per worker would increase substantially in some cities if labor were free to move. However, different from us, they limit their

[3] This resembles the literature on business cycle accounting that found that eliminating business cycles would lead to trivial effects (as in Lucas 1987, we do not have the necessary distributional cost to obtain larger losses as agents are identical, as emphasized by Storesletten, Telmer, and Yaron 2001).

[4] For example, the city with the highest productivity has more than 63 percent higher TFP than the city with mean TFP and 64 percent more than the median. Similarly, in the benchmark exercise, the range of amenities across cities amounts to 12 percent of utility.

[5] See Albouy (2008) for a more recent application of this methodology.

[6] Other work has emphasized the importance of frictions, productivity, and amenities in explaining the distribution of city sizes. Glaeser, Kolko, and Saiz (2001); Glaeser, Gyourko, and Saks (2005); Albouy (2008); and Rappaport (2008, 2009), for example, have underscored the importance of city amenities and institutional frictions. Others have emphasized the importance of the relative efficiency in production of the different urban areas (Holmes and Stevens 2002; Holmes 2005; Duranton and Overman 2008) or the geographic characteristics of the locations in which cities develop (Davis and Weinstein 2002; Bleakley and Lin 2012).

attention to efficiency and do not focus on the other components determining city size. Also relevant is a recent working paper by Behrens et al. (2011). It proposes a general equilibrium model of a system of cities that can be compared with the data. In contrast to our work, their paper emphasizes pro-competitive forces that work through firm selection to determine the productivity of cities. These forces lead to trade between cities, and so their counterfactual exercises focus on how shocks in one city affect the distribution of population and productivities in other cities.

More broadly, our work also relates to the literature on the size distribution of cities, but instead of taking a random growth approach in which city dynamics coming from productivity or preference shocks determine the size distribution (as in Gabaix 1999a, b, Duranton 2007, Rossi-Hansberg and Wright 2007, and Córdoba 2008), we use a model to decompose the individual city characteristics that lead to the cross-sectional distribution of city sizes. Since our model has no mobility frictions or specific factors, agents move across cities as a response to any temporary shock. In that sense, city dynamics play no role in our decomposition. Of course, the measured levels of efficiency, amenities, or frictions may still be the result of these dynamic mechanisms. To the extent that this is the case, our approach helps us assess the contribution of particular dynamic factors to the distribution of city sizes.

The rest of the paper is organized as follows. Section I introduces a simple urban model and explains the basic urban accounting exercise. Section II estimates a log-linear version of the structural equations using US data between 2005 and 2008 and obtains the reduced-form effects of the three main characteristics of cities on rents and city sizes. Section III performs counterfactual exercises using the empirical values of these city characteristics. Section IV applies our methodology to China, and Section V concludes. Online Appendix A shows how the population sizes of individual cities are affected when certain characteristics change. Online Appendix B describes in detail the urban dataset constructed.

I. The Model

We use a standard urban model with elastic labor supply so that labor taxes create distortions. Agents work in cities with idiosyncratic productivities and amenities. They live in monocentric cities that require commuting infrastructures that city governments provide by levying labor taxes. Large cities are more expensive to live in because of higher labor taxes and commuting costs but are large because of high levels of efficiency or local amenities. City governments can be more or less efficient in the provision of the public infrastructure. We refer to this variation as a city's "excessive frictions." In later sections we augment the model to include local externalities in production and amenities.

A. *Technology*

Consider a model of a system of cities in an economy with N_t workers. Goods are produced in I monocentric circular cities. Cities have a local level of productivity. Production in city i in period t is given by

$$Y_{it} = A_{it} K_{it}^{\theta} H_{it}^{1-\theta},$$

where A_{it} denotes city productivity, K_{it} denotes total capital, and H_{it} denotes total hours worked in the city.[7] We denote the population size of city i by N_{it}. The standard first-order conditions of this problem are

$$(1)\qquad w_{it} = (1-\theta)\frac{Y_{it}}{H_{it}} = (1-\theta)\frac{y_{it}}{h_{it}} \quad \text{and} \quad r_t = \theta\frac{Y_{it}}{K_{it}} = \theta\frac{y_{it}}{k_{it}},$$

where lowercase letters denote per capita variables (e.g., $y_{it} = Y_{it}/N_{it}$). Note that capital is freely mobile across locations so there is a national interest rate r_t. Mobility patterns will not be determined solely by the wage, w_{it}, so there may be equilibrium differences in wages across cities at any point in time. We can then write down the "efficiency wedge," which is identical to the level of productivity, A_{it}, as

$$(2)\qquad A_{it} = \frac{Y_{it}}{K_{it}^{\theta}H_{it}^{1-\theta}} = \frac{y_{it}}{k_{it}^{\theta}h_{it}^{1-\theta}}.$$

B. *Preferences*

Agents order consumption and hour sequences according to the following utility function

$$\sum_{t=0}^{\infty}\beta^t[\log c_{it} + \psi\log(1-h_{it}) + \gamma_i],$$

where γ_i is a city-specific amenity and ψ is a parameter that governs the relative preference for leisure. Each agent lives on one unit of land and commutes from his home to work. Commuting is costly in terms of goods.

The problem of an agent in city i_0 with capital k_0 is therefore

$$\max_{\{c_{i_tt}, h_{i_tt}, k_{i_tt}, i_t\}_{t=0}^{\infty}} \sum_{t=0}^{\infty}\beta^t[\log c_{it} + \psi\log(1-h_{it}) + \gamma_i]$$

subject to

$$c_{it} + x_{it} = r_t k_{it} + w_{it}h_{it}(1-\tau_{it}) - R_{it} - T_{it}$$

$$k_{it+1} = (1-\delta)k_{it} + x_{it},$$

where x_{it} is investment, τ_{it} is a labor tax or friction associated with the cost of building the commuting infrastructure, R_{it} are land rents, and T_{it} are commuting costs (as

[7] It would be straightforward to generalize this model to include human capital. We experimented with this, and doing so did not substantially change any of the theoretical or empirical results.

we will see below, $R_{it} + T_{it}$ is constant in the city so the location of the agent's home does not affect his choices).[8]

Throughout the paper we assume that we are in steady state so $k_{it+1} = k_{it}$ and $x_{it} = \delta k_{it}$. Furthermore, we assume k_{it} is such that $r_t = \delta$ (capital is at its Golden Rule level). The simplified budget constraint of the agent becomes

$$c_{it} = w_{it} h_{it}(1 - \tau_{it}) - R_{it} - T_{it}. \tag{3}$$

The first-order conditions of this problem imply $\psi \frac{c_{it}}{1 - h_{it}} = (1 - \tau_{it}) w_{it}$. Combining this expression with (1), we obtain

$$(1 - \tau_{it}) = \frac{\psi}{(1 - \theta)} \frac{c_{it}}{1 - h_{it}} \frac{h_{it}}{y_{it}}. \tag{4}$$

As in Chari, Kehoe, and McGrattan (2007), we refer to τ_{ti} as the "labor wedge." Although τ_{ti} is modeled as a labor tax, it should be interpreted more broadly as anything that distorts an agent's optimal labor supply decision. Part of the labor wedge may be an actual labor tax, but another part may reflect other distortions that act in the same way as a labor tax. As we show in Section IIB below, limiting ourselves to a strict tax interpretation risks missing a relevant part of the distortions.

Agents can move freely across cities so utility in each period has to be determined by

$$\overline{u} = \log c_{it} + \psi \log(1 - h_{it}) + \gamma_i, \tag{5}$$

for all cities with $N_{it} > 0$, where $\overline{u}$ is the economy-wide per period utility of living in a city.

C. *Commuting Costs, Land Rents, and City Equilibrium*

Cities are monocentric, all production happens at the center, and people live in surrounding areas characterized by their distance to the center, d. Cities are surrounded by a vast amount of agricultural land that can be freely converted into urban land. We normalize the price of agricultural land to zero. Since land rents are continuous in equilibrium (otherwise there would be arbitrage opportunities), this implies that at the boundary of a city, $\overline{d}_{it}$, land rents should be zero as well, namely, $R(\overline{d}_{it}) = 0$. Since all agents in a city are identical, in equilibrium they must be indifferent between where they live in the city, which implies that the total cost of rent plus commuting costs should be identical in all areas of the city. So

$$R_{it}(d) + T(d) = T(\overline{d}_{it}) = \kappa \overline{d}_{it} \text{ for all } d \in [0, \overline{d}_{it}],$$

since $T(d) = \kappa d$ where κ denotes commuting costs per mile.

[8] Since agents can move across cities, the subscript i depends on t, as written under the maximization sign. To save on notation, we drop this additional subscript.

Everyone lives on one unit of land, $N_{it} = \bar{d}_{it}^2 \pi$, and so $\bar{d}_{it} = (N_{it}/\pi)^{\frac{1}{2}}$. Thus, $R_{it}(d) + T(d) = \kappa\left(\frac{N_{it}}{\pi}\right)^{\frac{1}{2}}$ for all d. This implies that $R_{it}(d) = \kappa(\bar{d}_{it} - d)$ and so total land rents in a city of size N_{it} are given by $TR_{it} = \int_0^{\bar{d}_{it}} (\kappa(\bar{d}_{it} - d)\, d2\pi)\, dd = \frac{\kappa}{3}\pi^{-\frac{1}{2}} N_{it}^{\frac{3}{2}}$. Hence, average land rents are equal to $AR_{it} = \frac{2\kappa}{3}\left(\frac{N_{it}}{\pi}\right)^{\frac{1}{2}}$. Taking logs and rearranging terms, we obtain that

$$\ln(N_{it}) = o_1 + 2 \ln AR_{it}, \tag{6}$$

where o_1 is a constant. We can also compute the total miles traveled by commuters in the city, which is given by

$$TC_{it} = \int_0^{\bar{d}_{it}} (d^2 2\pi)\, dd = \frac{2}{3}\pi^{-\frac{1}{2}} N_{it}^{\frac{3}{2}}. \tag{7}$$

D. *Government Budget Constraint*

The government levies a labor tax, τ_{it}, to pay for the transportation infrastructure. Let government expenditure be a function of total commuting costs and wages such that

$$G(h_{it} w_{it}, TC_{it}) = g_{it} h_{it} w_{it} \kappa TC_{it} = g_{it} h_{it} w_{it} \kappa \frac{2}{3}\pi^{-\frac{1}{2}} N_{it}^{\frac{3}{2}},$$

where g_{it} is a measure of government inefficiency. That is, the government requires κg_{it} workers per mile commuted to build and maintain urban infrastructure.[9] The government budget constraint is then given by

$$\tau_{it} h_{it} N_{it} w_{it} = g_{it} h_{it} w_{it} \kappa \frac{2}{3}\pi^{-\frac{1}{2}} N_{it}^{\frac{3}{2}}, \tag{8}$$

which implies that the labor wedge can be written as

$$\tau_{it} = g_{it} \kappa \frac{2}{3}\left(\frac{N_{it}}{\pi}\right)^{\frac{1}{2}} \tag{9}$$

or

$$\ln \tau_{it} = o_2 + \ln g_{it} + \frac{1}{2} \ln N_{it}. \tag{10}$$

Although as we mentioned before, the notion of a labor wedge is not limited to a strict tax interpretation, here it is modeled as a tax that finances local infrastructure. However, it is straightforward to write down an alternative model, in which τ_{it} could

[9] Note the simplifying assumption that maintaining and building infrastructure requires a certain number of workers, not hours of work. The assumption simplifies the model since the number of hours does not appear in equation (8).

be reinterpreted as the fraction of time lost in commuting, that would lead to an equation similar to (10). We choose not to do so, since that would oblige us to move away from the more tractable monocentric city model.

E. *Equilibrium*

The consumer budget constraint is given by

$$c_{it} = w_{it} h_{it}(1-\tau_{it}) - R_{it} - T_{it} = (1-\theta)(1-\tau_{it})\,y_{it} - \kappa\left(\frac{N_{it}}{\pi}\right)^{\frac{1}{2}}.$$

To determine output we know that the production function is given by $y_{it} = A_{it} k_{it}^{\theta} h_{it}^{1-\theta}$ and the decision of firms to rent capital implies that $r_t k_{it} = \theta y_{it}$. Hence,

$$y_{it} = A_{it}\left(\frac{\theta y_{it}}{r_t}\right)^{\theta} h_{it}^{1-\theta} = A_{it}^{\frac{1}{1-\theta}}\left(\frac{\theta}{r_t}\right)^{\frac{\theta}{1-\theta}} h_{it}.$$

Using (4), we can derive

$$h_{it} = \frac{1}{1+\psi}\left(1 + \frac{\psi(R_{it}+T_{it})}{(1-\theta)(1-\tau_{it})}\frac{\left(\frac{r_t}{\theta}\right)^{\frac{\theta}{1-\theta}}}{A_{it}^{\frac{1}{1-\theta}}}\right)$$

and

$$c_{it} = \frac{(1-\theta)(1-\tau_{it})A_{it}^{\frac{1}{1-\theta}}\left(\frac{\theta}{r_t}\right)^{\frac{\theta}{1-\theta}} - (R_{it}+T_{it})}{1+\psi}.$$

The free mobility assumption in (5) implies that $\overline{u}_t = \log c_{it} + \psi \log(1-h_{it}) + \gamma_{it}$ for some $\overline{u}_t$ determined in general equilibrium so

$$\text{(11)}\quad \overline{u}_t + (1+\psi)\log(1+\psi) - \psi\log\psi$$
$$= \log\left((1-\theta)\left(1-\kappa g_{it}\frac{2}{3}\left(\frac{N_{it}}{\pi}\right)^{\frac{1}{2}}\right)\frac{A_{it}^{\frac{1}{1-\theta}}}{\left(\frac{r_t}{\theta}\right)^{\frac{\theta}{1-\theta}}} - \kappa\left(\frac{N_{it}}{\pi}\right)^{\frac{1}{2}}\right)$$
$$+ \psi\log\left(1 - \frac{\kappa\left(\frac{N_{it}}{\pi}\right)^{\frac{1}{2}}}{(1-\theta)\left(1-\kappa g_{it}\frac{2}{3}\left(\frac{N_{it}}{\pi}\right)^{\frac{1}{2}}\right)}\frac{\left(\frac{r_t}{\theta}\right)^{\frac{\theta}{1-\theta}}}{A_{it}^{\frac{1}{1-\theta}}}\right) + \gamma_{it}.$$

The last equation determines the size of the city N_{it} as an implicit function of city productivity, A_{it}, city amenities, γ_i, government inefficiency, g_{it}, and economy-wide variables like r_t and $\overline{u}_t$. We can use this equation to derive the effect of the three city-specific characteristics $(A_{it}, \gamma_{it}, g_{it})$ on N_{it}. First note that the LHS of (11) is decreasing in N_{it}. The LHS is also increasing in A_{it} and γ_i and decreasing in g_{it}. Hence, we can prove immediately that

$$(12) \qquad \frac{dN_{it}}{dA_{it}} > 0, \qquad \frac{dN_{it}}{d\gamma_i} > 0, \qquad \frac{dN_{it}}{dg_{it}} < 0.$$

So population increases in a more productive city or a city with more amenities, but it decreases in a city with a less efficient government.

The economy-wide utility level $\overline{u}_t$ is determined by the labor market clearing condition

$$(13) \qquad \sum_{i=1}^{I} N_{it} = N_t.$$

This last equation clarifies that our urban system is closed; we do not consider urban-rural migration.

II. Evidence of Efficiency, Amenities, and Frictions

To lend validity to our theoretical model, we estimate the size of the three derivatives in (12) and estimate the effect of land rents on population as in (6). When doing so, the general equilibrium nature of the model will be key.

A. *Empirical Approach*

We first estimate the "labor wedge" using equation (4) and the "efficiency wedge" in equation (2). Note that the empirical measure of the "efficiency wedge" is related not just to productivity but also to the relative price of city output. Although we have no way of disentangling these two terms, in a theory with multiple goods, relative price effects across cities would have isomorphic effects to changes in productivity. Hence, we just equate productivity to our measure of the "efficiency wedge."

The general equilibrium nature of the model is important. For example, if we regress the log of city size on the log of the labor wedge, we find a statistically significant positive effect (coefficient of 1.2360 and p-value of 0.000). But it would be wrong to conclude that higher frictions lead to greater city size. Rather, according to the theory, this positive association would reflect more productive cities being larger, and larger cities experiencing greater commuting costs. That is, in as far as greater commuting costs are due to cities being more efficient, they will be positively associated with city size. Only frictions "in excess" of this basic trade-off between efficiency and congestion will have a negative effect on city size. In what follows we propose a methodology that accounts for these general equilibrium links by decomposing these different effects.

We start by estimating the following equation:

$$(14) \qquad \ln N_{it} = \alpha_1 + \beta_1 \ln A_{it} + \varepsilon_{1it}.$$

The value of β_1 yields the effect of the "efficiency wedge" on city population. According to the model, $\beta_1 > 0$ by (12). Furthermore, $\ln \tilde{N}_{it}(A_{it}) = \beta_1 \ln A_{it}$ is the population size explained by the size of the "efficiency wedge". In contrast, ε_{1it} is the part of the observed population in the city that is unrelated to productivity; according to the model it is related to both g_{it} and γ_{it}. We can thus define the function $\tilde{\varepsilon}_1(g_{it}, \gamma_{it}) \equiv \varepsilon_{1it}$.

Since the "efficiency wedge" increases population size, total commuting increases, which affects the "labor wedge" according to equation (10). This is the standard urban trade-off between productivity and agglomeration. We can estimate the effect of productivity on the labor wedge by using equation (10) and the decomposition of $\ln N_{it}$ into $\ln \tilde{N}_{it}(A_{it})$ and ε_{1it} provided by equation (14). Hence, we estimate

$$\ln \tau_{it} = \alpha_2 + \beta_2 \ln \tilde{N}_{it}(A_{it}) + \varepsilon_{2it}. \tag{15}$$

According to equation (10), $\beta_2 > 0$. That is, a city that is more productive and so has more population will be more distorted. We denote the effect of efficiency on distortions by $\ln \widetilde{\tau_{it}} = \beta_2 \ln \tilde{N}_{it}(A_{it})$. Equation (10) also implies that the error term ε_{2it} is related to g_{it} and to $\tilde{\varepsilon}_1(g_{it}, \gamma_{it})$ (since the labor wedge depends on all factors affecting population and not just on $\ln \tilde{N}_{it}(A_{it})$). Hence, we define $\tilde{\varepsilon}_2(g_{it}, \tilde{\varepsilon}_1(g_{it}, \gamma_{it})) \equiv \varepsilon_{2it}$.[10]

We now use equation (6) to decompose the effect from all three elements of $(A_{it}, \gamma_i, g_{it})$. To do so, we estimate

$$\ln(AR_{it}) = \alpha_3 + \beta_3 \ln \widetilde{\tau_{it}} + \beta_4 \varepsilon_{1it} + \beta_5 \varepsilon_{2it} + \varepsilon_{3it} \tag{16}$$

using median rents for AR_{it}. The model has clear predictions for β_3, β_4, and β_5. In particular, it implies $\beta_3 > 0$, since by equations (6) and (12) efficiency has a positive effect on population, which has a positive effect on the level of distortions and on average rents. This is the standard city size effect. The effects of γ_{it} and g_{it} are determined by the estimates of β_4 and β_5. Note that ε_{1it} and ε_{2it} depend on both γ_{it} and g_{it}. However, since $\varepsilon_{2it} = \tilde{\varepsilon}_2(g_{it}, \tilde{\varepsilon}_1(g_{it}, \gamma_{it}))$ depends only on γ_{it} through ε_{1it} and we are including ε_{1it} directly in the regression, β_5 will capture only the effect of changes in g_{it} on land rents. So, β_5 captures the effect of g_{it} on frictions and therefore average rents. Higher distortions imply a higher τ_{it}. Hence, the model implies that higher g_{it}, and therefore higher τ_{it} and ε_{2it}, implies lower population and lower rents (see (12)). Thus β_5 should be negative. Similarly, since we are controlling for the effect of g_{it} by including ε_{2it}, β_4 will capture the effect of ε_{1it} on land rents controlling for g_{it}, which is the effect of γ_{it} on land rents, since $\varepsilon_{1it} = \tilde{\varepsilon}_1(g_{it}, \gamma_{it})$. Hence, the model implies that β_4 should be positive by equations (6) and (12). Our model implies that rents are a non-linear function of $(A_{it}, \gamma_i, g_{it})$. In contrast, equation (16) assumes that it is a linear function. Adding higher degree polynomials and interaction terms to this

[10] Note that if we were to substitute for $\ln \tau_{it}$ and $\ln \tilde{N}_{it}(A_{it})$ in equation (15) one obtains an equation that includes y_{it} and h_{it} on the left- and right-hand side of the equation. This is standard when using general equilibrium frameworks. In our theory, this is not a problem when estimating β_2 since productivity is exogenous. However, in practice, it might be the case that measurement error in y_{it} and h_{it} leads to an upward bias in the estimate of β_2. We recognize this problem but point to the fact that aggregate output at the city level is one of the better measured variables in our sample and it is measured directly by the BEA.

relationship can in principle be important. We do so in our empirical implementation below, though this does not affect results in any substantial way.

Note that we can then use equation (6) to relate average rents and population sizes. So we estimate equation (6) as

$$\ln(N_{it}) = \alpha_4 + \beta_6 \ln AR_{it} + \varepsilon_{4it}. \tag{17}$$

According to the model, in a circular city, $\beta_6 = 2 > 0$.

B. *Effects of Efficiency, Amenities, and Frictions on City Size*

To bring the model to the data, we construct a new dataset on US metropolitan statistical areas (MSAs) for the period 2005–2008. Apart from output and rental prices, few ready-to-use data are available at the MSA level. We rely on a combination of proxies previously used in the literature and micro-data to come up with measures for the other relevant variables, such as consumption, hours worked, and capital. Online Appendix B1 provides details on the construction of the dataset and Table B4 presents the data and the computed city characteristics. Computing the "labor wedge" and the "efficiency wedge" requires making assumptions on the values of some parameter values. In particular we chose $\psi = 1.4841$ and $\theta = 0.3358$ to match aggregate moments as in McGrattan and Prescott (2010). We also set $r = \delta = 0.02$, a standard value for interest rates satisfying our assumption in Section IB.

Before implementing the empirical exercise of the previous section, it may be useful to return to the discussion of what exactly the labor wedge is measuring. As we argued above, the labor wedge is not just determined by taxes but by anything that distorts the optimal labor decision of agents. Still, if taxes are part of what the labor wedge is, we would expect the cross-city variation in taxes to be related to the cross-city variation in labor wedges. We can decompose the labor wedge into taxes and other distortions such that

$$(1 - \tau_{it}) = (1 - \tau'_{it})\left(\frac{1 - \tau_{ith}}{1 + \tau_{itc}}\right), \tag{18}$$

where τ_{it} is our measure of the labor wedge, τ_{ith} is the labor tax rate, τ_{itc} is the consumption tax rate, and τ'_{it} are other distortions. Thus, we expect our measure of the total labor wedge, $(1 - \tau_{it})$, to be correlated with $(1 - \tau_{ith})/(1 + \tau_{itc})$. To explore this, we collect data on labor taxes and consumption taxes at the MSA level and find a positive correlation of 0.27 (statistically significant at the 1 percent level). At the same time, we find that local taxes make up on average one-third of the labor wedge. Therefore, although local taxes are positively correlated with the labor wedge, an important part of the labor wedge consists of other distortions. At the end of Section IIIA we will discuss the correlation between the labor wedge and measures of these other distortions in more detail.

We now turn to the empirical exercise of the previous section. We pool the data for 2005–2008 and include time dummies in all regressions. One further difference is that we also include an interaction term $\varepsilon_{1it}\,\varepsilon_{2it}$ in equation (16), since we found it to be statistically highly significant. We denote the coefficient associated with

Table 1

j	β_j	SE	p-value	Theoretical prediction
1	2.0964	0.3727	0.000	+
2	0.4127	0.0234	0.000	+
3	0.1283	0.0461	0.005	+
4	0.0959	0.0070	0.000	+
5	−0.2020	0.0420	0.000	–
6	2.1400	0.3824	0.000	2
7	−0.1841	0.0437	0.000	–
Observations	768			

Notes: The coefficients β_j refer to the estimates of $\ln N_{it} = \alpha_1 + \beta_1 \ln A_{it} + \varepsilon_{1it}$, $\ln \tau_{it} = \alpha_2 + \beta_2 \ln \tilde{N}_{it}(A_{it}) + \varepsilon_{2it}$, $\ln(AR_{it}) = \alpha_3 + \beta_3 \ln \widetilde{\tau_{it}} + \beta_4 \varepsilon_{1it} + \beta_5 \varepsilon_{2it} + \varepsilon_{3it}$, and $\ln (N_{it}) = \alpha_4 + \beta_6 \ln AR_{it} + \varepsilon_{4it}$, as explained in Section IIA.

this interaction term β_7. Standard errors for equations (16) and (15) are obtained by bootstrapping, since some of the regressors are estimated.[11] The results are presented in Table 1.

As is clear from Table 1, all coefficients have the signs implied by the model and are highly significant. The estimation of equations (14), (15), (16), and (17) yields R^2 values of, respectively, 0.14, 0.37, 0.25, and 0.18. The model implies that in a circular city $\beta_6 = 2$. The value we find is close to two and we fail to reject the hypothesis that it is equal to 2 at the 5 percent level.

These results allow us to reach several conclusions. First, highly efficient cities are more populated. This is consistent with numerous empirical studies in the literature. Second, efficient cities are more distorted. Frictions are larger as a result of these cities being larger. The frictions that result from more efficient cities being larger are positively related to median rents, since they are the result of the higher efficiency. Third, frictions that exceed the ones explained by efficiency have a negative effect on land rents and city size. Finally, cities that are larger due to amenities also exhibit larger median rents.

The model and the empirical exercise have allowed us to assess the impact of the three city characteristics (efficiency, excessive frictions, and amenities) on land rents and population size. It has also made the point that the general equilibrium effects are important. However, the empirical log-linear model that we have used does not inherit the entire structure of the model. For example, the derivatives in (12) need not be constant. It is therefore important to go beyond this simple empirical exercise to capture the full richness of the theoretical model. In the next section we propose a methodology to obtain the value of the three key city characteristics, and we use the model to perform counterfactual exercises. We show how the model can be made to account for all of the variation in city sizes if we identify amenities as a residual from the theory.

[11] Correcting the standard errors for clustering by MSA does not qualitatively change any of the results, except for β_3, which is no longer statistically significant.

III. Counterfactual Exercises

In this section we start by showing how to identify the different city characteristics (efficiency, amenities, and frictions) and then run a number of counterfactual exercises. Initially we focus on the benchmark case without externalities, as this helps lay out the basic workings of the model. We later extend the model to the more realistic case of local externalities in production and amenities. The role played by externalities can then easily be uncovered by comparing the results with the benchmark case.

A. *Methodology and Identification of City Characteristics*

The model provides a straightforward way of performing counterfactual exercises. Equation (11) implies that

$$C_1(\overline{u}_t, \gamma_{it}) - \log(C_2(A_{it}, r_t))$$
$$= (1+\psi)\log\left(1 - \left(\kappa\frac{2}{3}g_{it} + \frac{\kappa}{C_2(A_{it}, r_t)}\right)\left(\frac{N_{it}}{\pi}\right)^{\frac{1}{2}}\right)$$
$$- \psi\log\left(1 - \kappa\frac{2}{3}g_{it}\left(\frac{N_{it}}{\pi}\right)^{\frac{1}{2}}\right),$$

where

$$C_1(\overline{u}, \gamma_{it}) = \overline{u}_t + (1+\psi)\log(1+\psi) - \psi\log\psi - \gamma_{it},$$
$$\text{and } C_2(A_{it}, r_t) = (1-\theta)\frac{A_{it}^{\frac{1}{1-\theta}}}{\left(\frac{r_t}{\theta}\right)^{\frac{\theta}{1-\theta}}}.$$

If g_{it} and τ are small, using the approximation $\log(1-x) \approx -x$,[12] we obtain

$$N_{it} = \frac{\pi}{\kappa^2}\left(\frac{\log(C_2(A_{it}, r_t)) - C_1(\overline{u}, \gamma_{it})}{\frac{(1+\psi)}{C_2(A_{it}, r_t)} + \frac{2}{3}g_{it}}\right)^2. \tag{19}$$

Note that the approximation results in exactly the same derivatives with respect to $(A_{it}, \gamma_{it}, g_{it})$. Furthermore, $\partial N_{it}/\partial\overline{u} < 0$, namely, a higher equilibrium utility (smaller total population) makes concentration of workers in a given city less likely since concentration implies congestion costs.[13]

[12] This approximation works best if τ_{it} and κ are small. In the exercise below the approximation error is likely very small.

[13] Throughout this section we calculate an agent's utility based on his labor and capital income but not on the income he obtains from land rents. Land is owned by absentee landlords and so rental income does not enter an agent's utility and does not affect his decision to move. We have calculated all of the results below if we use the alternative assumption that workers in a city own a diversified portfolio of land in the city and so obtain as income

We can use the equation above to calculate N_{it} given the values of $(A_{it}, \gamma_{it}, g_{it})$ and other parameter values. We can also use these expressions to run counterfactual exercises. In particular we can calculate counterfactual distributions of city sizes assuming that all cities have similar values of any of the exogenous city characteristics $(A_{it}, \gamma_{it}, g_{it})$. Note that $\overline{u}_t$ has to be selected such that the resulting city sizes satisfy the labor market clearing condition (13). In order to perform any of these exercises we first need to develop a strategy to calculate $(A_{it}, \gamma_{it}, g_{it})$ for each city. $A_{it} = y_{it}/\left(k_{it}^{\theta}\, h_{it}^{1-\theta}\right)$ can be calculated directly from available data on y_{it}, h_{it}, and k_{it}.[14] Obtaining values for the other two city characteristics is more complicated. First note that equation (10) can be used to estimate g_{it}. Based on this equation we can run the simple log-linear regression

$$\ln \tau_{it} - \frac{1}{2} \ln N_{it} = \alpha_5 + \varepsilon_{5it}. \tag{20}$$

We use data for 2005–2008 and add time dummies. Equation (10) then implies that $\varepsilon_{5it} = \ln g_{it}$.[15] Note that since in expression (9) both κ and g_{it} enter multiplicatively we can only identify $\ln g_{it}$ relative to the constant α_5 (which includes the unknown parameter κ) by imposing that the mean of $\ln g_{it}$ is 0. This explains why we refer to this city characteristic as "excessive frictions." That is, it measures the frictions over and above what city size would predict. To be clear, we are identifying g_{it} by attributing the variation in τ_{it} after controlling for city size, N_{it}, to g_{it}, but the level of this relationship is attributed to the transport cost parameter κ as we explain below.

We still have to obtain the value of γ_{it}. There are a variety of ways to do this. The one that is most consistent with the theory is to use equation (19) and solve for the set of γ_{it} that makes the model match city sizes exactly, given some normalization of $\overline{u}$ (we set $\overline{u} = 10$). We can then fix γ_{it} and perform counterfactual exercises. Of course, this exercise depends on the value of all parameters in the model. We use the same parameters used above. One extra important parameter in determining γ_{it} is κ, for which we have not assigned a value yet. To obtain a value for κ, notice that equation (9), together with regression (20), implies that

$$\alpha_5 = \ln\left(\frac{2}{3}\right) + \ln \kappa - \frac{1}{2} \ln \pi,$$

the average rents. The results under this assumption are essentially identical (utility differs only by less than 0.001) to the ones with absentee landlords, both in the case with and without externalities. The reason is that we are always normalizing the level of utility that reproduces the size distribution to $\overline{u} = 10$ and only relative utilities matter to determine location decisions.

[14] This is what we did in the empirical implementation above. An alternative way of calculating the relevant productivity term without using k_{it} (which is potentially poorly measured in the data) is to use the prediction of the model on capital allocation. In particular the model implies that $k_{it} = \theta y_{it}/r_t$. Equation (19) assumes that capital is determined in this way and so this method has the advantage of being theoretically more consistent (although it does not use the actual data on capital stocks). We have added capital in both ways and found the results to be similar. The correlation of the model-based capital stock measure and the empirical capital stock measure is 0.9. Therefore, we omit here the exercise with the theoretical levels of capital and focus on the one where we use the empirical measure of the capital stock.

[15] Alternatively, we could run $\ln \tau_{it} = \alpha_5 + \beta_8 \ln N_{it} + \varepsilon_{5it}$. This is the same as (20) without restricting β_8 to be equal to $1/2$. Using efficiency as an instrument for population, we find $\beta_8 = 0.4$, similar to the 0.5 predicted by the theory.

and so, given a value for α_5 from regression (20), we can calculate κ. The estimation gives a value of $\kappa = 0.002$. The time dummies we include are mostly not significant, and their values are so small that adding them would not change the value of κ.

Given that our identification strategy of the different city characteristics depends on the model's structure (and its functional form assumptions), it might be interesting to compare our estimates with common empirical direct measures of these characteristics. This is especially true for the amenities, which are not directly measured, but estimated as the residual that makes the model match the observed city sizes. We follow the quality-of-life literature (see, e.g., Rappaport 2007) and collect data on climate (such as average low temperature in January, annual precipitation, annual precipitation days, and July heat index), proximity to water (oceans, Great Lakes, and major rivers), and other life-quality measures from different city rankings (such as transport, education, health, crime, arts, recreation, and leisure). As can be seen in Table B.1 in online Appendix B, of the 23 correlations between our estimates of amenities and these alternative measures, 22 have the expected sign, of which 18 are statistically significant at the 10 percent level. As for efficiency, we likewise find a strong positive correlation between our efficiency measure and wages (0.79) and labor productivity (0.90). See Table B.2 in online Appendix B.

Finding measures of frictions that can be directly related to labor wedges or excessive frictions is harder. As we have emphasized above, excessive frictions can be related to taxes, commuting costs, excessive government expenditures given the magnitude of infrastructure projects, as well as other labor market or land use frictions. Importantly, some of these frictions are fundamental and will cause cities to be small, while others will just be the result of congestion in larger, and more complex, cities. In principle, fundamental sources of frictions should be correlated with our measure of excessive frictions, while the actual observed frictions should be related to the labor wedge τ. We attempted to disentangle the impact of g and τ empirically in Section II. Here, given that our measures of frictions are all observed outcomes at the city level and not underlying sources of frictions, we correlate these measures with the labor wedge τ. Table B.3 in online Appendix B presents the results. Of the 11 correlations, ten have the right sign and eight are significant at the 5 percent level. Land use regulation does not seem to be related to our notion of frictions and public sector unions are not statistically significant, although private ones are. Taxes, local expenditures and commuting costs are all positively and significantly related to the labor wedge as well. Overall, the comparison of our three city characteristics with standard direct measures seems to suggests that our identification strategy yields city characteristics that can be interpreted in standard ways.

B. *Counterfactuals*

We are now ready to perform a number of counterfactual exercises. After analyzing the effect of commuting costs, the main focus will be on exploring the relative importance of different characteristics (efficiency, amenities, and excessive frictions) in determining the city size distribution. In particular, we are interested in understanding how changes in city characteristics affect city sizes, welfare, and the reallocation of people.

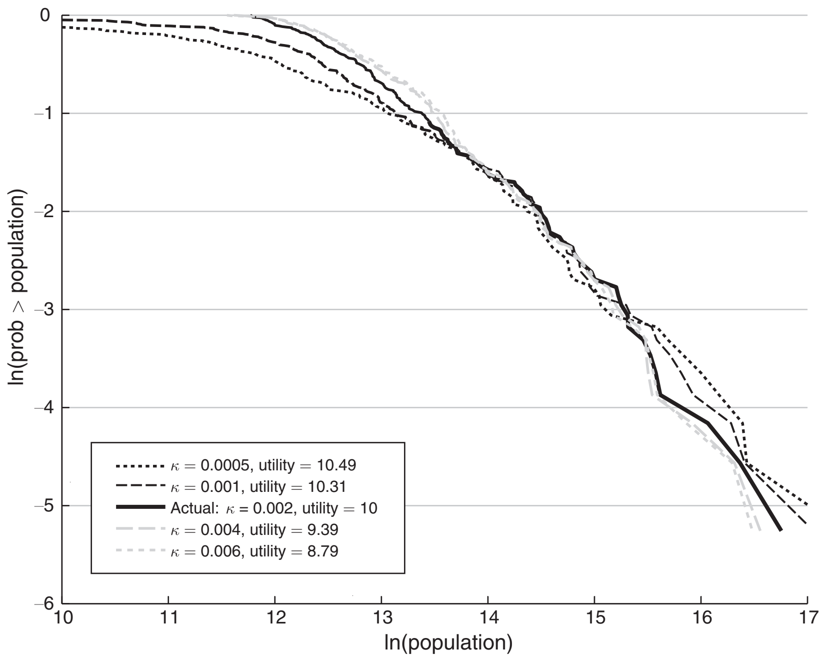

Figure 1. The City Size Distribution for Different Levels of Commuting Costs

Figure 1 shows the actual distribution of city sizes in the US and counterfactual distributions of city sizes if we increase or decrease commuting costs κ, given the distribution of characteristics. The results are presented in the standard log population—log rank plots in which a Pareto distribution would be depicted as a line with slope equal to minus the Pareto coefficient. As is well-known, the actual distribution is close to a Pareto distribution with coefficient 1. By construction the model matches the actual distribution exactly for $\kappa = 0.002$. In all exercises we normalize the benchmark utility $\overline{u} = 10$. This normalization implies that the difference in utility from living in the city with the highest amenities relative to the one with the lowest amenities amounts to 11.7 percent of utility. In all counterfactual exercises we solve for the value of $\overline{u}$ for which the labor market clears, i.e., the sum of population across cities equals the actual total urban population.[16]

As can be seen in Figure 1, larger commuting costs make the largest cities smaller and the smaller cities larger, leading to a less dispersed distribution of city sizes. Doubling commuting costs decreases utility by about 6.1 percent. Production moves

[16] One of the goals of the counterfactual exercises is to quantify the welfare effects of different changes. Given that we have a log utility function in consumption, the normalization of the benchmark utility to ten implies that a 1 percent increase in utility is equivalent to a 10 percent increase in consumption. Both measures are somewhat arbitrary. On the one hand, it is unclear what a 10 percent increase in consumption means in terms of welfare if utility depends on many other factors like leisure and the quality of life in a city. On the other hand, the effect in terms of utility depends on the arbitrary normalization. Subject to these caveats, the rest of the paper maintains the focus on utility, with the understanding that any percentage difference in utility should be multiplied by ten in order to transform it into a percentage difference in consumption. Of course, in as far as relative statements are concerned, such as when we compare the US and China, there is no difference between both ways of expressing welfare differences.

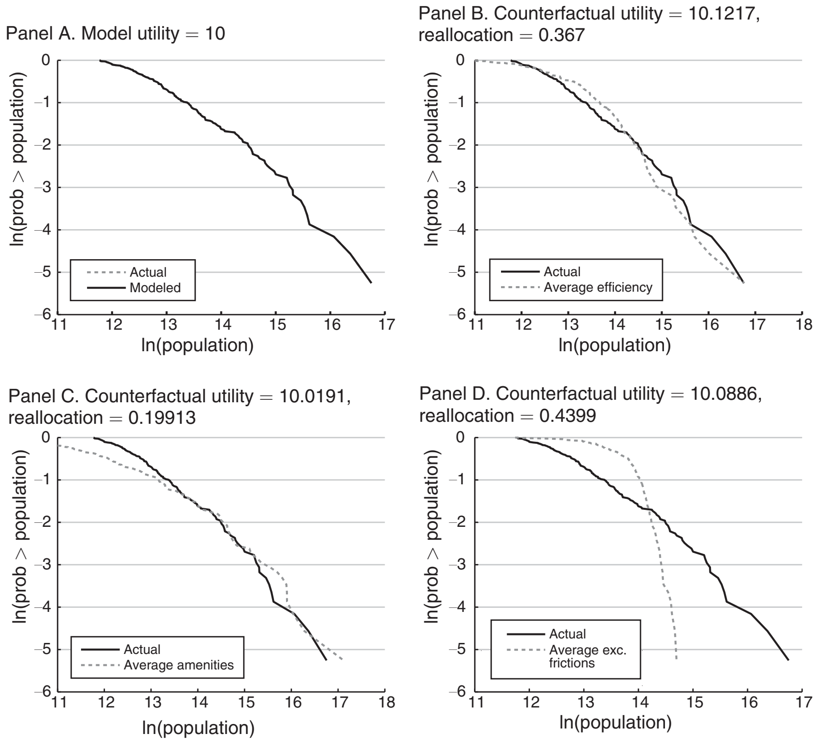

Figure 2. Counterfactuals without Differences in One City Characteristic, $\kappa = 0.002$

away from the larger and most productive cities, which leads to welfare losses. Halving commuting costs increases dispersion and raises utility by 3.1 percent. Note that the smallest cities now become much smaller. The main advantage of some of these cities was their small size and their corresponding low level of congestion. As commuting costs decrease, this advantage becomes less important and their size decreases further.

Figure 2 shows three counterfactual exercises where we shut down differences in each of the three city characteristics (efficiency, amenities, and excessive frictions), respectively. In all cases we eliminate differences in a particular characteristic by setting its value to the population weighted average. We then calculate the utility level that clears the labor market, so total urban population is identical in all cases. Note that smoothing out spatial differences always leads to an increase in utility. Differences create dispersion in the city size distribution and by equation (7) total commuting costs are convex. So utility in the model tends to increase if population is more evenly distributed in the 192 cities in our sample. If we eliminate differences in all three components so that all sites are identical, welfare would increase by 1.54 percent and all cities would have a population of 1 million 68 thousand people. Of course, this increase in welfare does not constitute an upper bound, since the distribution of the different city characteristics, as well as their correlation, matters for the final results.

The counterfactual exercises in Figure 2 show that eliminating differences in efficiency, amenities, or excessive frictions has a modest effect on utility. In all cases utility would increase by less than 1.5 percent. The limited effect on utility is due to several reasons. The most obvious one is that population can reallocate across cities. But there are others. For example, the effect of a negative shock to productivity on utility is also mitigated by people working less, by lowering the cost of providing city infrastructure, and by the fact that utility does not only depend on production but also on amenities. In as far as regional policies aim to reduce differences in, say, efficiency or amenities across space, these results suggest that their effect on welfare is likely to be modest.

In spite of the small effect on utility, the effect on the size of individual cities is large. In the case of excessive frictions this is clear from Figure 2. Eliminating differences in excessive frictions tends to hurt larger cities and benefit smaller ones: New York and Los Angeles would lose up to 90 percent of their populations, whereas Santa Cruz and Trenton would gain, respectively, 145 percent and 326 percent.[17] This suggests that larger cities have been successful, not just because of higher efficiency but because they have been able to eliminate barriers and other frictions that hinder growth. However, there are notable exceptions: the population of Buffalo, a fairly large metropolitan area, would increase by 36 percent if differences in excessive frictions were eliminated.

Although perhaps less obvious from Figure 2, equalizing efficiency or amenities also has a large effect on the size of individual cities. Larger cities would typically decline in size if they had average levels of efficiency. For example, Los Angeles would lose 29 percent of its population. The respective figures for New York and Chicago would be losses of 77 percent and 46 percent. When equalizing amenities, the picture is more mixed. One pattern that emerges is that many East Coast cities would gain, whereas many West Coast cities would lose. For example, New York and Philadelphia would increase their populations by 44 percent and 39 percent if differences in amenities were eliminated, whereas Los Angeles and San Diego would lose 8 percent and 42 percent of their populations. One would expect that equalizing efficiency or amenities would tend to benefit smaller cities. This is indeed sometimes the case—for example, the population of Fargo would increase by 183 percent if its amenities were equal to the average—but by no means always. Some of the smaller cities decline because they lose their only comparative advantage. One such example is Santa Fe: if it had average amenities, it would lose 82 percent of its population. Intermediate-sized cities often benefit as they tend to experience a boost in productivity or amenities and are already attractive enough in terms of other characteristics. These cities also grow because of the reallocation of population from larger cities.

Online Appendix A shows figures and maps with the percentage changes in population for individual cities when we set one of the city characteristics to its weighted average. In terms of the geographic distribution of city characteristics, we find that most cities on the West Coast and in Florida would lose population if we eliminated amenity differences. This is consistent with Rappaport and Sachs (2003) and Rappaport (2007), who argue that the concentration of population in coastal areas

[17] Whenever we mention city names, we are referring to the MSA. For example, Los Angeles refers to Los Angeles-Long Beach-Santa Ana and New York refers to New York-Northern New Jersey-Long Island.

with nice weather has to do increasingly with a quality-of-life effect. Central regions would tend to lose population if we eliminated efficiency differences, as would most of the northeastern regions. Perhaps the sharpest geographical pattern emerges when we eliminate excessive frictions. Many of the Rust Belt cities in the Midwest and the Northeast would gain population if we equalized frictions across cities. Examples include Rochester (+37 percent), Syracuse (+120 percent), Milwaukee (+16 percent), Allentown-Bethlehem (+14 percent), and Toledo (+108 percent). This is an indication that governance problems, as well as other labor market frictions, like unions, may be important in these places.

The effect of the different city characteristics on the distribution of city sizes hides some of the implied population reallocation in these counterfactuals. That is, cities are changing ranking in the distribution even if the overall shape of the distribution does not always exhibit large changes, as in the case of amenities or efficiency. We can calculate reallocation following Davis and Haltiwanger (1992) by adding the number of new workers in expanding cities as a proportion of total population when we change from the actual distribution to the counterfactual. This measure of reallocation is 37 percent when we eliminate differences in TFP, 20 percent when we eliminate amenities, and 44 percent when we eliminate excessive frictions: large numbers given the modest welfare gains. As a benchmark, the same reallocation number for the US economy over a 5-year interval is around 2.1 percent (over the period 2003–2008).

Figure 3 shows the counterfactual distributions of city sizes when we equalize two of the three characteristics across cities. The distributions therefore show the heterogeneity in city sizes generated by a single characteristic. Note that neither efficiency on its own nor amenities on their own can explain the relatively large sizes of both the smallest and the largest cities in the actual distribution. This is because some of these cities are attractive in terms of their other characteristics, making them larger than their efficiency or their amenities on their own would imply.

Figure 4 shows a counterfactual exercise when we set excessive frictions in all cities equal to the tenth, fiftieth, or ninetieth percentile of the distribution of excessive frictions. First note that just eliminating the variation in excessive frictions across cities and setting them at the median decreases welfare by 2.5 percent. The figure shows that reducing frictions in all cities to the tenth percentile increases the dispersion of city sizes. Large cities gain the most in terms of population from the change, and many small cities exit. Utility increases by 4.2 percent relative to setting the level of frictions at the median. An opposite effect results from setting frictions to the ninetieth percentile, although the changes in the distribution are in general smaller. In this case utility declines by 5.5 percent relative to the case where excessive frictions are at the median. An increase in excessive frictions makes large cities particularly expensive since large cities use the commuting technology more intensively (as we discussed in Section ID). As a result, the economy produces in more uniformly sized cities and so fails to exploit the differences in efficiency and amenities across cities. This leads to a considerable change in utility.

Robustness Exercises.—To assess the robustness of our results, we do a number of additional exercises. A first robustness check concerns the elasticity of commuting costs relative to population. Our theoretical model assumes that population

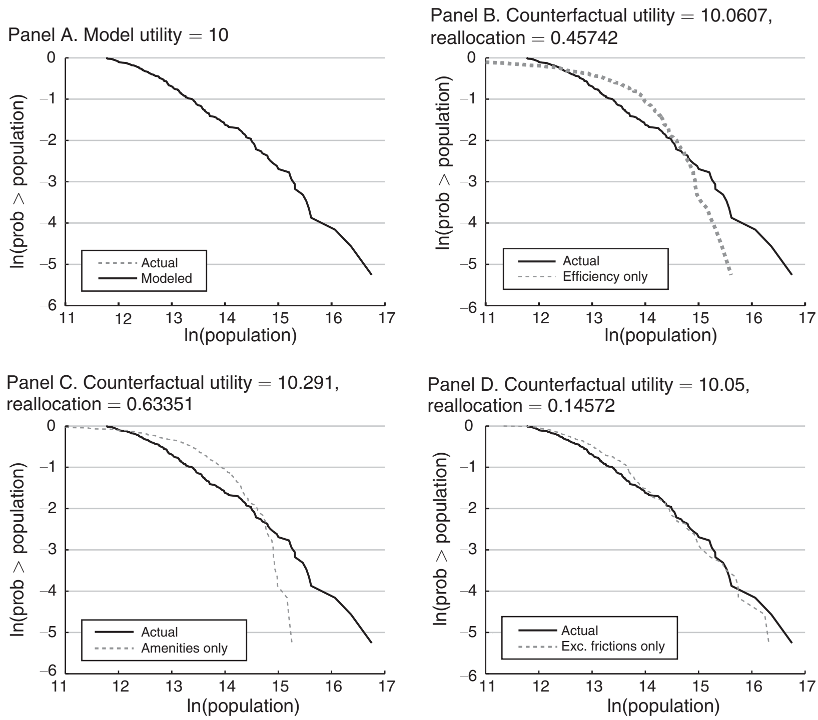

Figure 3. Counterfactuals with Differences in Only One City Characteristic, $\kappa = 0.002$

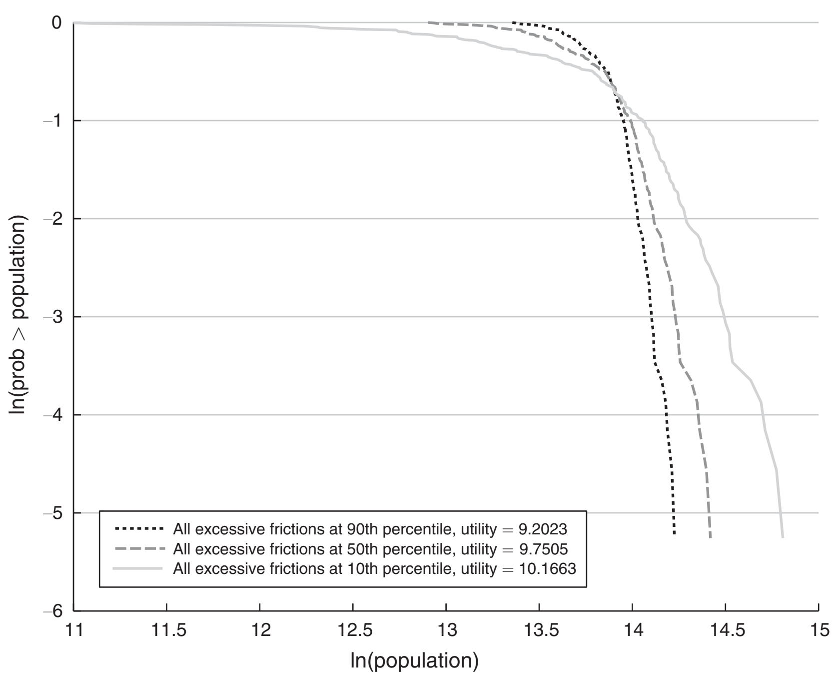

Figure 4. Changing the Level of Excessive Frictions

density is independent of size, implying an elasticity of commuting costs relative to population of 0.5. It is straightforward to generalize the model to allow for the possibility of larger cities being more dense.[18] By regressing the log of area on the log of population, we can then easily derive the implied elasticity. Depending on the definition of a city (MSA versus incorporated places with a population of more than 100,000), we find a value of 0.25 or 0.5, respectively. Our theoretical value is therefore within the range of plausible values. To evaluate whether an elasticity of 0.25 would overall be more consistent with external data, we once again compute correlations between the estimated amenities and the observed amenities, based on climate, life quality, and proximity to water, and find a much worse fit than in the case of an elasticity of 0.5.[19]

It is nevertheless instructive to redo our basic counterfactual exercise in Figure 2 for an elasticity of 0.25 (and the corresponding higher value of $\kappa = 0.048$, since κ depends negatively on the elasticity). Recall that with an elasticity of 0.5 differences in excessive frictions have a relatively large effect on the city size distribution, compared to differences in amenities or efficiency. In that case it is costly for cities to be large and so the ones that become big must have very low excessive frictions. In contrast, when we drop the elasticity to 0.25, becoming large is less costly, so that big cities no longer require excessive frictions that are that low. The cross-city dispersion in excessive frictions therefore declines. But if so, the dispersion in amenities must increase in order for the model to be able to account for the actual city size distribution. So amenities play a larger role in determining the shape of the size distribution of cities, and as a result, eliminating differences in amenities yields larger welfare gains (4.2 percent). Equalizing excessive frictions also leads to larger gains (13.6 percent) since in the case of a lower elasticity we are penalizing large cities much less by setting their excessive frictions to the average level. The welfare gains from equalizing efficiency decrease to 0.64 percent. We present the results of this exercise in Figure A9 in online Appendix A.

Since we have repeatedly argued that the labor wedge is about more than taxes, a second robustness check analyzes whether our results change when we define the labor wedge as being only due to distortions other than taxes. Following the same decomposition as in (18), we now define the labor wedge as only the part that is due to other "distortions." The results are largely unchanged: the shapes of the counterfactual city size distributions are very similar to the benchmark exercise. The only slight difference is that the welfare effects are slightly larger when eliminating differences in efficiency (1.9 percent instead of 1.2 percent) or amenities (0.5 percent instead of 0.2 percent), and slightly smaller when eliminating differences in excessive frictions (0.7 percent instead of 0.9 percent). This is easily understood: by considering only the part of the labor wedge which is due to other frictions, the cross-city variation in labor wedges is reduced and, with it,

[18] Consider a city in which population density increases with population size according to N^{ξ}, where $\xi \geq 0$. Then population in the city is given by $N_{it} = \overline{d}_{it}^2 \pi N_{it}^{\xi}$. Since $\overline{d}_{it}^2 \pi$ is the area of the city, we can use this equation to estimate ξ using data on area and population. Average commuting costs are given by $AC_{it} = \frac{2}{3}\kappa\pi^{-\frac{1}{2}}N_{it}^{(1-\xi)/2}$, so the elasticity of commuting costs to population is equal to $(1 - \xi)/2$. So in the monocentric city model with constant density, where $\xi = 0$, this elasticity is equal to $1/2$.

[19] With an elasticity of 0.25, of the 23 correlations computed, only 12 have the right sign, of which only ten are statistically significant at the 10 percent level. This is a substantially worse outcome than with an elasticity of 0.5.

the cross-sectional variation in excessive frictions. Since differences in excessive frictions therefore play less of a role in explaining the city size distributions, differences in efficiency and amenities must play, in relative terms, more of a role. As a result, eliminating differences in excessive frictions has a slightly smaller welfare effect, whereas eliminating differences in efficiency and amenities has a slightly larger welfare effect.

A third robustness check concerns the level of commuting costs κ, which we have estimated to be equal to 0.002. The larger κ, the smaller the relative importance of productivity differences, since it becomes more costly to live in large productive cities and the people that live in them tend to work less since τ is larger. If we set $\kappa = 0.006$, a threefold increase, the total reallocation if we equalize efficiency across locations drops from around 37 percent to 12 percent, with a 0.7 percent increase in utility, half of the effect we had with $\kappa = 0.002$. Reallocations decrease from 20 percent to 8.5 percent when cities have average amenities, and utility now goes up by 0.3 percent, instead of by 0.2 percent. The reallocation if we set excessive frictions to their average level remains essentially constant at 43 percent. The changes in city sizes are highly correlated in the exercises with the two different values of κ.

A final robustness check studies the role retirees play in our calculations. Our measure of average hours worked is affected by the distribution of retirees across cities. In particular, cities with many people older than 65, many of whom do not work, appear very distorted since labor supply per person is low. Of course, distorted cities in turn attract agents who do not want to work, and so there are good arguments to include all agents in our calculation of hours worked. Still, it is useful to assess the extent to which our results are driven by retirees rather than active agents deciding on how many hours to work. For this purpose we redo our main exercise excluding agents older than 70, or older than 65, from the calculation of hours worked. All the main results remain unchanged and the quantitative impact of retirees is in general small. So retirees do not drive our conclusions. Figure A10 in online Appendix A presents these results. Not including older agents has the largest impact when we eliminate differences in efficiency across cities. The reason is that retirees go to cities that have high amenities but are not necessarily very productive. Excluding them increases hours worked in those cities. This lowers measured productivity, thereby increasing dispersion in efficiency across cities.

C. *Adding Production Externalities*

So far we have taken productivity in a particular city to be exogenously given. We have assumed that the efficiency of a particular site is not affected by the level of economic activity at that site. That is, so far efficiency has explained agglomeration, but we have assumed away the reverse link by which agglomeration explains efficiency. Of course, a standard view in urban economics suggests that agglomeration is, at least in part, created by an increase in productivity coming from a rise in the number of people living in a given city. Including these agglomeration effects in our calculations has the potential to change our results, as this will have an endogenous effect on the size of a city.

To incorporate these effects, we start with equation (19) but recognize that the term A_{it}, which captures the efficiency of city i, is a function of the size of the city N_{it}. In particular, we now let

$$A_{it} = \tilde{A}_{it} N_{it}^{\omega}. \tag{21}$$

That is, the level of productivity is now a function of exogenous productivity $\tilde{A}_{it}$, and city size, N_{it}, where the elasticity of the efficiency wedge with respect to population is given by ω. Note that externalities operate within cities, and not across cities. We can then use the previous calculation of efficiency wedges, using equation (2), and divide by population raised to ω. The result is a set of new exogenous efficiency levels $\tilde{A}_{it}$. We then substitute (21) in (19) and solve for the γ_{it}s that yield the city's exact population levels. Excessive frictions are calculated as before. With all the city characteristics in hand, we now perform the same set of counterfactual exercises as before. Note that equation (19) now includes N_{it} in the productivity terms and so cannot be solved analytically. But we can solve the system of non-linear equations numerically to obtain city sizes in the counterfactual exercises.

We still need to determine a suitable value for ω. Of course, the estimation of equation (14) is not useful to determine ω. In fact, this equation will fit exactly as in the data in our simulation of the actual economy. Instead, we rely on the literature, which suggests a fairly robust estimate of $\omega = 0.02$ (see, among others, Carlino, Chatterjee, and Hunt 2007; and Combes et al. 2012). We therefore start with an initial value of 0.02 and perform some robustness checks. We also set $\kappa = 0.002$ as estimated in the previous section. Clearly, allowing for production externalities reduces the dispersion in exogenous efficiency since the high endogenous efficiency of large cities is now largely due to their size, rather than to their high exogenous efficiency. For example, the exogenous efficiency of Los Angeles, which we had estimated to be 9 percent above the country's average in the absence of externalities, now drops to being 5 percent below the average once we allow for externalities.

Figure 5 presents the exercise with externalities in the case where we eliminate each characteristic individually. First note that when we eliminate one of the characteristics, small cities tend to become a lot smaller and some no longer survive. We use a cutoff of log(8) to determine the cities that exit, which implies that cities become towns with about 3,000 people. The smallest MSA in our sample has a population of 129,000. In particular, 15 cities exit when we equalize $\tilde{A}_{it}$ across cities to its population weighted mean, 29 cities exit when we set amenities to their average value, and six cities exit with average excessive frictions. As in the case without externalities, these are cities that lose their only comparative advantage. With externalities, this loss gets compounded, leading some small cities to exit.

Including externalities implies that large cities tend to become a lot smaller when eliminating differences in excessive frictions, whereas their size does not change much when equalizing exogenous efficiency or amenity levels. This latter result can be explained by the smaller dispersion in exogenous efficiency or amenities. Comparing this case to the one without externalities, utility can increase or decrease. On the one hand, introducing externalities reduces the underlying differences across cities, implying utility gains because of convex commuting costs. On the other hand, differences in city characteristics allow cities to exploit external effects, implying

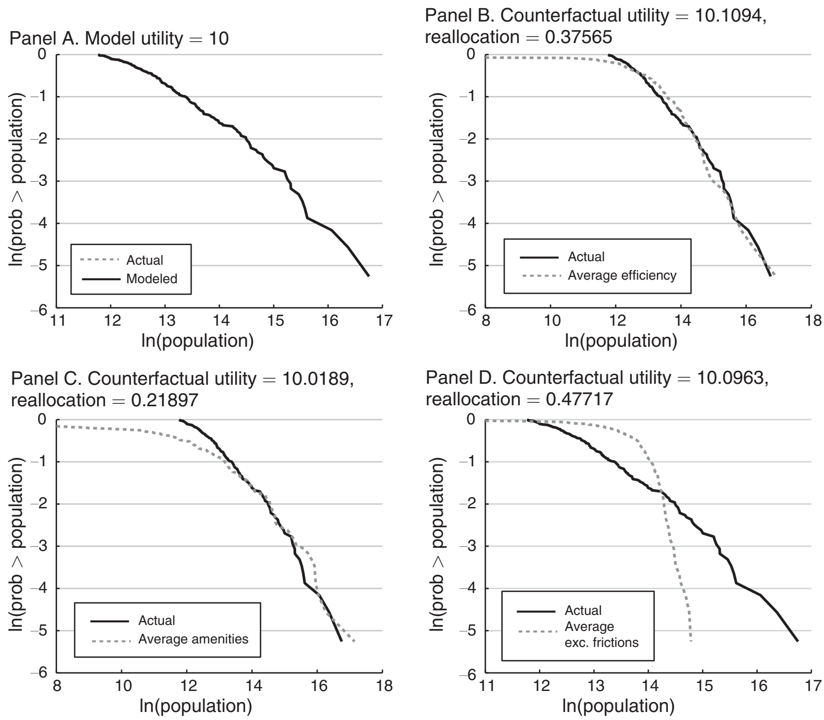

Figure 5. Counterfactuals without Differences in One City Characteristic and Externalities, $\kappa = 0.002, \omega = 0.02$

utility losses when making cities more alike. As a result of these opposing forces, utility is virtually unchanged, relative to the case without externalities. Introducing externalities slightly increases the total reallocation required in the counterfactuals. Compared to the case without externalities, the total reallocation required in the counterfactual tends to go slightly up. This happens because the changes introduced by the elimination of these characteristics get compounded through the effect of changes in population on efficiency.

Doubling the externality to $\omega = 0.04$, closer to the estimate reported by Behrens, Duranton, and Robert-Nicoud (2010), exacerbates the effects described above. More cities either exit or become very small. The results suggest that selection of cities in the presence of externalities can be important. Relative to the case without externalities, the increase in externalities does not significantly change the utility gains obtained if we equalize one of the city characteristics.

Adding externalities in production implies that the equilibrium allocation we compute is no longer efficient. In contrast to the exogenous productivity case, city planners could improve on the equilibrium allocation by subsidizing urban agglomeration. We can compute the optimal allocations in the case with production externalities by letting a representative firm internalize the external effect on productivity. Since the differences in welfare between the cases with and without externalities are so small, it is not surprising that the effect of these optimal urban policies is necessarily small as well. In fact, the gain in utility is only 0.58 percent. Given that the informational requirements for these urban policies is extremely high, it is not clear

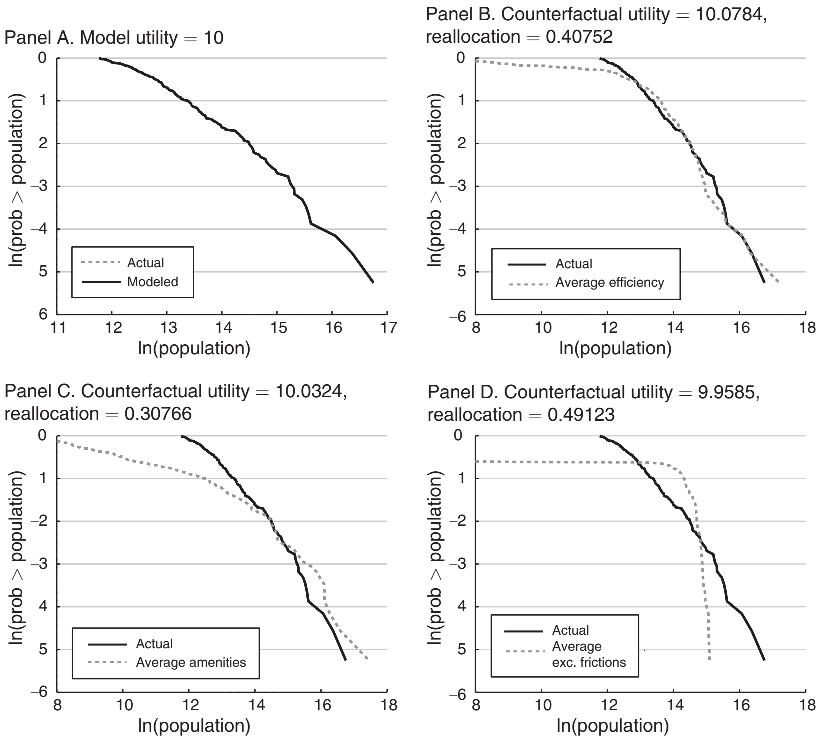

Figure 6. Counterfactuals without Differences in One City Characteristic and Externalities, $\kappa = 0.001$, $\omega = 0.02$, $\zeta = 0.02$

that actual policy can achieve these small gains. Figure A11 in online Appendix A compares the optimal and actual allocations.

We should also mention here that the exercise with externalities leads to the possibility of multiple equilibria in the size of cities. For many cities it will be the case that, given the equilibrium utility level, there is only one equilibrium size. But for other cities there may be several possible equilibrium sizes. Our theory does not provide a way of selecting between these equilibria so we always present the one that requires less reallocation. That is, we always initialize the search for a solution of the size of a city at its actual size.

D. *Adding Externalities to Amenities*

We can also add externalities in the amenities a city provides. That is, we can let the utility from living in a particular city depend on the size of the city directly. People live in New York because living around a large number of people leads to a scale that provides them with a variety of goods and services, and interactions with people, which they enjoy. We have modeled the preference to live in a particular city through the amenity γ_{it}. So we can simply let $\gamma_{it} = \tilde{\gamma}_{it} N_{it}^{\zeta}$, where now $\tilde{\gamma}_{it}$ is the exogenous amenity and ζ is the elasticity of amenities with respect to population size.

We repeat the exercise in Figure 5 but now we let $\zeta = 0.02$ as well. Figure 6 shows the results. The results are qualitatively similar but now we observe that more cities become extremely small. That is, the selection mechanism we emphasized above becomes stronger. Equalizing city characteristics implies that externalities are not exploited as much. This effect is bigger because of the two types of externalities. This explains why utility decreases relative to Figure 5 for the counterfactuals on both efficiency and excessive frictions. The opposite result for amenities reflects that some of the larger cities have worse amenities, so that eliminating amenity differences leads to a positive, though small, increase in utility.[20]

Perhaps surprisingly, the effects on utility of eliminating the differences in any of our three characteristics are small in magnitude, even though the implied reallocation of agents is, again, fairly large. Eliminating efficiency differences increases utility by 0.8 percent but implies that 41 percent of agents reallocate. The same reallocation statistics when we eliminate amenity differences is 31 percent and 49 percent for excessive frictions. Most of the reallocation comes from the extensive margin. Many cities become extremely small: the city selection effect. Once again, by equalizing a given characteristic, some small cities lose their only comparative advantage. This loss is compounded by the existence of externalities, so that some smaller cities become so small that they exit. However, the reallocation has small effects on agents' utility, since even though small cities do not experience the benefits of large externalities, they are not distorted through taxes since city infrastructure is cheap. The slope of the envelope of the value of living in different cities is extremely flat, so agents switching locations leads to small utility gains.

City selection can be most easily understood by studying what happens if we eliminate differences in all three city characteristics. In this case the urban structure has 117 cities with 1,752,525 agents and the other 75 cities essentially disappear and preserve a population of only 538 agents in each of them. Without any city characteristics, but with externalities, there are two city sizes that give agents identical utility levels, and the number of cities in each size is determined by the market clearing condition so that all agents are housed in some city. So there is an equilibrium that specifies the number of cities of each type. The utility level in this case is 9.991. Thus, eliminating all differences in city characteristics yields small losses to agents as most agents live in smaller cities and some live in very small towns that have no congestion or infrastructure costs but also no gains from agglomeration. Note again that since there are no shocks, we know that there may be multiple equilibria. As before, in all cases we compute the equilibrium with minimal reallocation of agents across cities, which yields a level of utility closest to the one in the actual distribution, namely, 10.

Figure 7 shows counterfactuals eliminating differences in all city characteristics for different elasticities of city efficiency and amenities to population size. Clearly, as we increase the elasticity, and therefore the externality, we still have two sizes of cities, but the larger the externality, the larger and fewer the larger cities. So larger externalities make the larger and smaller cities larger and increase the number of

[20] Undoubtedly, there is a lot more uncertainty about the value of ζ than about the value of ω. In fact, it is not entirely clear that city size leads to larger amenities. Hence, for robustness purposes, we have computed an alternative exercise where we let $\zeta = -0.02$ instead of 0.02 (the rest of the parameters are kept exactly as in Figure 6). Comparing the results with those in Figure 6 indicates that the welfare gains from eliminating heterogeneity in any one of the city characteristics are of similar magnitude (1.05 percent for efficiency, 0.17 percent for amenities, and 0.93 percent for excessive frictions). The main change is that the city selection effect is now much smaller. This is natural since the negative externality of size on amenities favors small cities.

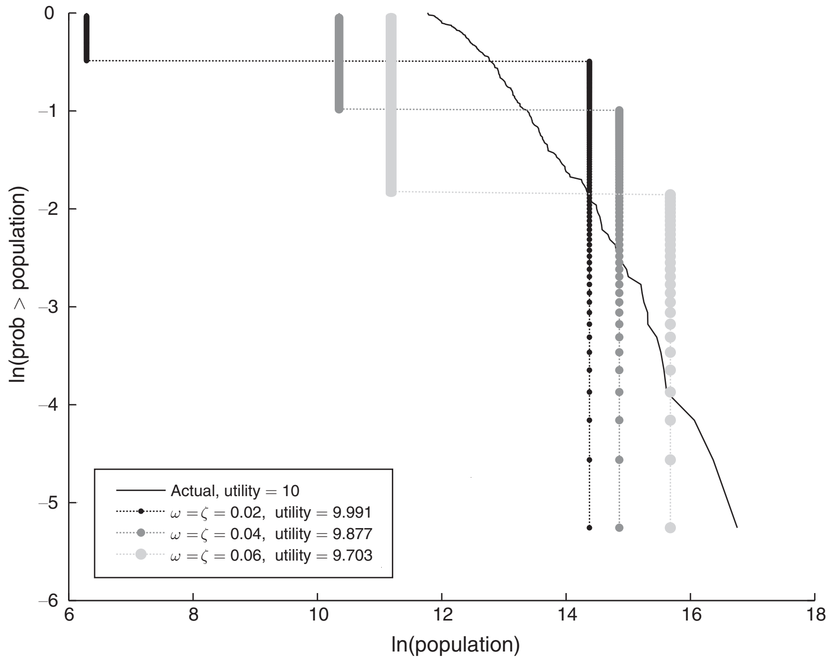

Figure 7. Counterfactuals without Differences in City Characteristics, $\kappa = 0.002$

small cities. Furthermore, the larger the externality, the lower the utility in the counterfactual without differences in city characteristics. When externalities are large, differences across cities create agglomeration and result in benefits. Eliminating them yields lower utility.

IV. China

The most important finding so far is that eliminating differences in efficiency, amenities, or excessive frictions leads to large reallocations of people but to small welfare effects. It is unclear whether this conclusion is general, inherent to the model, or specific to the US. To address this question, we carry out a similar analysis for the case of China.

The details of the database we built for 212 Chinese cities for 2005 are given in online Appendix B.2. The data we need are the same as for the US and come from China City Statistics and from the 2005 1 percent Population Survey. Two further comments are in order. First, in China a prefecture-level city is an administrative division below a province and above a county. Prefecture-level cities cover the entire Chinese geography. They include both the urban parts and the rural hinterlands and are therefore not the same as cities in the US. Luckily, the data tend to provide separate information for the urban parts of cities (referred to as districts under prefecture-level cities or also as city proper). In our database we focus on those districts under prefecture-level cities, as these are the closest equivalents to MSAs in the US. Second, when using Chinese data, the issue of their quality inevitably comes up.

City-level data tend to be collected by local statistical agencies and are commonly perceived to be of very high quality.[21]

In order to estimate Chinese city characteristics we need to use parameter values specific to the Chinese economy. We set the capital share of income $\theta = 0.5221$ and the real interest rate $r = 0.2008$ (Bai, Hsieh, and Qian 2006). Consistent with our analysis of the US, we use the same approach as McGrattan and Prescott (2010) to estimate ψ for China and find a value of 1.5247. We use a value of $\kappa = 0.001$, which we find using the same methodology as in the US case. Online Appendix B.2 provides more details. In any case, the exact values for the different parameters play a limited role. When using the US parameter values for our exercise on China, the main findings are largely unchanged. The reason is that modifying any of the parameter values has a limited impact on the distribution of the relevant variables across cities. We set externalities equal to zero in all exercises with Chinese data.

For the purpose of comparison, we run the same benchmark counterfactual exercise as in the case of the US. This exercise equalizes in turn each of the three city characteristics (efficiency, amenities, and excessive frictions). Results for China are shown in Figure 8 and should be compared to the results for the US in Figure 2.[22] The most striking difference with the US is that the welfare effects in China are now an order of magnitude larger. If all Chinese cities had the same level of efficiency, welfare would increase by 47 percent, and if all had the same level of amenities, welfare would increase by 13 percent. The corresponding figures for the US are 1.2 percent and 0.2 percent.[23] Another way of understanding the difference in magnitude is that in order to maintain utility at its original level, it would be enough to give all Chinese cities an efficiency level corresponding to the lowest 27th percentile.

Note also that the total reallocation of population is similar to that in the US even though the welfare gains are much larger. Some examples can be informative: both Beijing and Shanghai would lose about 97 percent of their population if we equalize productivity. In contrast, if we equalize amenities, Beijing would lose 10 percent of its population, while Shanghai would lose only 1 percent. Finally, when equalizing excessive frictions, the loss in population in Beijing and Shanghai would be 29 percent.

When equalizing efficiency or amenities across Chinese cities, the size distribution becomes more dispersed, with the larger cities being larger and the smaller cities being smaller. In contrast, in the US the larger cities become smaller if we shut down efficiency differences, whereas the effect is less clear when we turn off amenity differences. Large cities in China are in general more efficient, but quite a few

[21] See Au and Henderson (2006) for a further discussion of the quality of city-level data in China. Population data are based on people with local household registration (the *hukou* population), and thus exclude temporary migrants (*liudong renkou*). We can get an estimate of total population by comparing data on GDP and GDP per capita, since the NBS requires local GDP per capita to include temporary migrants. The average difference between the total and the *hukou* population in 2005 was 7.7 percent. See also footnote 23.

[22] There is one difference with the exercise we perform for the US. When eliminating differences in a city characteristic, we set it equal to the median, rather than the weighted mean, of all cities. This change underestimates the difference between China and the US. We do this differently because the weighted mean of Chinese city TFP would make cities so productive that an equilibrium with the same number of cities does not exist.

[23] City characteristics in China were set equal to their median. Given that the median is below the mean, the figures for China should be interpreted as lower bounds. Including temporary migrants (see footnote 21), we obtain differences in welfare that are still larger than in the US. Welfare would increase by 30 percent in the case of efficiency and by 5 percent in the case of amenities.

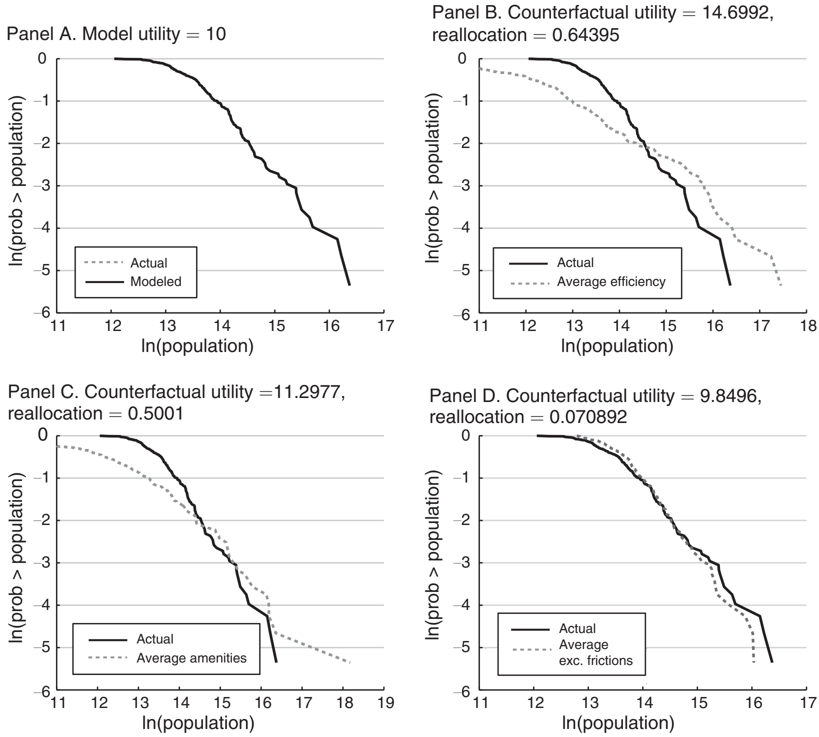

Figure 8. China Counterfactuals without Differences in One City Characteristic

have worse amenities than smaller cities. If all cities had the same amenities, some of the larger ones would become more attractive, making them even larger. Given that larger cities tend to be more efficient, it is not immediately obvious why equalizing efficiency levels skews the distribution toward larger cities. What happens here is that some of the intermediate-sized cities, with higher amenities than the largest cities, now get higher levels of efficiency and end up becoming very large cities. In other words, when equalizing amenities, the already larger cities become even larger, whereas when equalizing efficiency, some intermediate-sized cities become much larger. This is consistent with population reallocation being lower when equalizing amenities (50 percent) than when equalizing efficiency (64 percent).

Another potential explanation is that large cities, even though they are better at everything, are kept artificially small by migration restrictions. The relatively small population combined with large efficiency would lead our model to estimate low amenities for these cities, leading to the mechanism described above. Shenzhen, one of the *special economic zone* cities, is a case in point: its population would more than quadruple if we equalize amenities. This would be in line with the finding of Au and Henderson (2006) that Chinese cities are too small. This interpretation is also consistent with the much larger welfare effects we find in China compared to the United States. If migratory restrictions are keeping highly efficient cities in China from reaching their optimal size, then equalizing amenities would have an equivalent effect as lowering migratory barriers to these cities. As this leads to a more efficient allocation of factors of production, the welfare effect could be substantial.

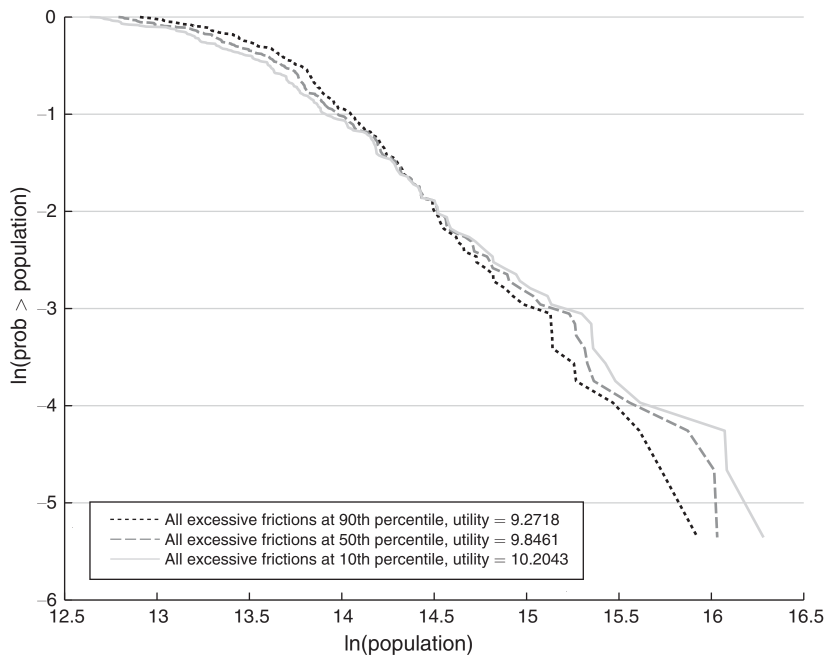

Figure 9. Changing Excessive Frictions in China

We have not yet discussed the effect of equalizing excessive frictions across cities. When setting excessive frictions equal to the median, we find that welfare declines by 1.5 percent. The relatively small effect does not imply that excessive frictions are small in China. To see this, Figure 9 shows the impact on welfare and the city size distribution of setting excessive frictions to the ninetieth and the tenth percentile of the distribution of excessive frictions, a similar exercise to the one we presented for the US in Figure 4. If all cities had the excessive frictions of the ninetieth percentile, welfare would drop by 5.8 percent, and the larger cities would become smaller. Likewise, if all cities had the excessive frictions of the tenth percentile, welfare would increase by 3.5 percent, and the larger cities would become larger. Overall, the figure indicates that the changes in the size distribution of cities are smaller than in the US, but the utility implications are similar in magnitude. In China, excessive frictions are less important in explaining the dispersion in the size distribution of cities, but their average level is as high as in the US.

V. Conclusion

In this paper we have decomposed the size distribution of cities into three main characteristics: efficiency, amenities, and excessive frictions. We find that each one of these components is important. Eliminating differences in any of them would imply large reallocations of people. In the US the welfare gains or losses associated with particular distributions of these characteristics are modest. Eliminating any differences in characteristics across cities yields welfare gains of at most 2 percent.

Note that the actual population movements required can be larger than 40 percent, so any small reallocation cost would turn these gains into losses. We also include externalities in both productivity and amenities. The welfare effects associated with eliminating particular characteristics of cities are even smaller in these cases, although we find a strong selection effect in the counterfactual distributions. Namely, many cities exit or become extremely small.

The small effects in terms of welfare are not inherent to the model. Applying the same methodology to China reveals welfare effects that are an order of magnitude higher. Of course, the impact on welfare could be further enhanced if one were to add distributional effects in a model with heterogeneous agents. Also, if the number of cities were smaller, reallocating by moving to similar cities becomes more difficult, implying larger welfare effects.

The results suggest that regional policies aimed at reducing spatial differences are likely to have a small effect in the United States. In China, however, the impact could be much larger. As argued before, this may be related to the high population mobility in the US, and the lack thereof in China.

More generally, we have provided a simple methodology to study the determinants of the size distribution of cities. This methodology can be useful in comparing urban systems across countries. We have illustrated this by also analyzing the case of China. The data requirements to do the exercise are not extreme, and it could shed light on the sources of differences in urban systems across countries. Such a comparison will be informative about the effectiveness and welfare effects of different policies aimed at making the location of agents across cities more efficient.

The framework we presented could of course be extended to include additional features. The demand for housing could be explicitly modeled and we might want to allow for heterogeneity in skills or preferences. Indeed, larger cities may differ from smaller cities in their skill composition, in particular its dispersion if not its mean,[24] and an agent's preference for living in nice weather might depend on his age. This would surely affect some of our results, since heterogeneity might lead to less mobility across cities than assumed in the present framework. But there is a trade-off to be faced. Including such features would undoubtedly make the model more realistic, but it would also increase the data requirements, thus limiting the scope for comparing urban systems across countries.

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