Why Are Some Cities so Crowded?

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December 2004*

Keywords: Population Density, Productivity, Quality-of-Life, Compensating Differentials, Economic Growth

JEL Classifications: O400, O510, R110, R120

Population density varies widely across U.S. cities. A calibrated general equilibrium model in which productivity and quality-of-life differ across locations can account for such variation. Individuals derive utility from consumption of a traded good, a nontraded good, leisure, and quality-of-life. The traded and nontraded goods are produced by combining mobile labor, mobile capital, and non-mobile land. An eight-fold increase in population density requires an approximate 50 percent productivity differential or an approximate 20 percent compensating differential. A thirty-two-fold increase in population density requires an approximate 95 percent productivity differential or a 33 percent compensating differential. Empirical evidence suggests productivity and quality-of-life differentials of this magnitude are plausible. The model implies that broad-based technological progress can induce substantial migration to localities with high quality-of-life.

*Thank you for advice and feedback to V.V. Chari, Steven Durlauf, Charles Engel, Vernon Henderson, Ruben Hernandez-Murillo, Peter Klenow, and Naryana Kocherlakota. Taisuke Nakata and Aarti Singh provided excellent research assistance. The views expressed herein are those of the author and do not necessarily reflect the position of the Federal Reserve Bank of Kansas City or the Federal Reserve System.

1 Introduction

Population density varies hugely across U.S. local areas. Among urbanized areas with population of at least 100,000, the most crowded (Los Angeles) has a density eight times that of the least crowded (Barnstable, MA). Among municipalities with population of at least 100,000, the ratio between the most and least crowded (New York City and Chesapeake, VA) is forty-five.

Economic theory can account for such variation by assuming that more crowded areas are characterized by higher levels of productivity and quality-of-life. But are the degrees of variation in local productivity and local quality-of-life plausible? The present paper will argue that they are. Specifically, the paper derives a general equilibrium model of locational choice. Individuals derive utility from consumption of a traded good, a nontraded good, leisure, and quality-of-life. The lattermost is a public good that is assumed to exogenously vary across localities. The traded and nontraded goods are produced by combining mobile labor, mobile capital, and immobile land. Total factor productivity in the production of the traded good is assumed to exogenously vary across localities. The resulting model is similar to those in Henderson (1974, 1987, 1988), Haurin (1980), and Upton (1981).

Numerical solutions show that for one city to have eight times the population density of another, its productivity in the production of traded goods must be approximately 50% higher. For it to have thirty-two times the population density of another, its productivity must be approximately twice as high. Such productivity differences are well within the range experienced by OECD nations.

Alternatively, for one city to have eight times the population density of another, it must have a higher quality-of-life that individuals in the uncrowded city value at 20% of their consumption. For it to have thirty-two times the population density of another, it must have a higher quality-of-life that individuals in the uncrowded city value at 33% of their consumption. The implied range of consumption expenditures is well within what is observed across European Union nations.

The paper proceeds as follows. Section 2 describes some empirical regularities among U.S. localities against which a model of locational choice can be compared. Section 3 presents the model. Section 4 discusses the model's parameterization. Section 5 describes the model's numerical results. Section 6 explains how an identical increase in productivity experienced by all cities can induce a migration towards those with higher quality-of-life. A last section briefly concludes.

2 Empirical Motivation

The motivation for the present paper is the huge observed variation in population density across U.S. localities. A "locality" is meant to connote a geographic place where a given group of people both live and work. For the United States, there are several geographic units that partially satisfy this. Table 1 shows rankings of population density for four such units. In all cases, observations are limited to those with a population in 2000 of at least 100,000.

For metropolitan areas, the geographically largest of the four units, population density varies by a multiplicative factor of 375 (Panel A). For present purposes, however, this span greatly overstates the relevant range of crowdedness. The model below assumes that all land is productive and occupied. But metropolitan areas are constructed as the combination of whole counties. Especially in the West, much of the land area in many metropolitan counties is essentially empty expanses of desert or forest. Unsurprisingly, this exaggeration of the span of crowdedness also arises using counties as the unit of observation (Panel B).

A much better geographic unit for measuring the range of crowdedness are "urbanized areas". Essentially, they are constructed as the combination of the densely-settled land areas within metropolitan areas. The 255 urbanized areas underlying Panel C together account for 63.6% of the continental U.S. population in 2000 but just 2.2% of its land area. For comparison, the 254 metropolitan areas underlying Panel A account for 79.8% of the continental U.S. population and 22.7% of its land area. So the urbanized areas encompass most of the population of metropolitan areas but exclude most of their land area. Among urbanized areas with population of at least 100,000, population density varies by a multiplicative factor of 8.

A problem with measuring crowdedness using urbanized areas it that doing so greatly understates the population density experienced by the millions of people living in the most crowded cities. For example, the New York City urbanized area has a population density of 5.3 thousand persons per square mile. But for the 8 million people living in New York City proper, population density is 26.4 thousand persons per square mile.

To address this understatement, crowdedness can be measured using municipalities with a population of at least 100,000. Many of these municipalities are the primary cities of metropolitan areas. The remainder are suburbs within larger metropolitan areas.[1] Among such municipalities, population density varies by a multiplicative factor of 45. But this probably overstates the relevant range of crowdedness. The model below assumes that people live and work within the same locality. But people often live in one municipality and work in a different one. Moreover several of the least crowded municipalities include large swathes of barely inhabited land.

For the theoretical exercise that follows, multiplicative factors of 8 and 32 are used as respective lower and upper bounds on the degree to which crowdedness varies across U.S. urban localities. Recall that 8 is the ratio of the most-dense to least-dense U.S. urbanized area. And 32 is the approximate ratio of the most-crowded municipality to the least-crowded urbanized area.

The model below predicts that wages, house prices, leisure time, and several other local outcomes will vary systematically with population density. Such variables are indeed observed to do so. Rankings of urbanized areas for several of these variables are shown in Table 2.

Median annual wage and salary earnings vary by a multiplicative factor of 3.5 across urbanized areas (Panel A). But the elasticity of median wage and salary earnings with respect to population density is just 0.075. And population density accounts for just 2% of their variation. Of course, median earnings may capture a varying composition of workers across urbanized areas. Panel B tries to control for this by looking at the variation in wages for a presumably homogeneous group of workers, registered nurses. In this case wages vary by an approximate multiplicative factor of 2. The corresponding elasticity with respect to density is 0.145. And density accounts for 21.5% of the variation in observed wages. Using aggregate data for the 341 employment zones in France in 1998, Combes, Duranton, and Gobillon (2004) report a more modest elasticity of wages with respect to density of 0.049 but a much higher R^2 of 51%.

Unsurprisingly, housing prices increase with population density. Panels C and D show the variation in median house rent and median house price. The former varies by a multiplicative factor of 3; the latter, by a multiplicative factor of almost 11. The respective

[1]Formally, the municipalities underlying Panel D are places administered by a central government unit and legally recognized by their respective state government.

elasticities are 0.201 and 0.398. The respective accounted shares of variation are 12.9% and 13.9%. Note that median rent and median house sales price represent expenditures rather than prices. Actual prices are likely to vary by even more since individuals should consume lower quantities of housing where prices are high.

Table 2's last two panels show that both commuting times and the share of housing units in large multifamily structures also vary greatly and are positively correlated with population density.

3 Model

Consider a world made up of two open economies, one small and one large. The small economy can be interpreted as a "locality", a well-defined market for factors and goods. The large economy can be interpreted as the aggregate of numerous other localities. Within each economy, land, labor, and capital combine to produce a traded and a nontraded good. Each economy contains a fixed amount of land. Between the two economies, capital and labor are perfectly mobile. The amount of capital in each is passively determined based on a required rate of return. The equilibrium division of population between the two assures that individuals achieve an identical level of utility regardless of where they live.

The small and large economies potentially differ with respect to *exogenous* underlying productivity and quality-of-life. Productivity captures local public goods that enter as arguments in local firms' production functions. Examples might include natural harbors, navigable rivers, and central locations. Quality-of-life captures local public goods that enter as arguments in local residents' utility functions. Examples might include moderate climates, scenic vistas, and natural recreational endowments.

High small-economy productivity and quality-of-life are the two potential sources of small-economy crowding. Against these, a fixed quantity of small-economy land is the *only* source of small-economy congestion.

3.1 Firms

Within each economy ($i = s, l$), perfectly-competitive firms employ a constant-returns-to-scale (CRS) production function that combines land, capital, and labor (D_i, K_i, and L_i) to produce a traded numeraire good and a nontraded good, (X_i and Z_i). The nontraded good must be consumed in the economy in which is produced. Aggregate production within each economy is given by

$$X_i = \mathrm{A}_{X,i}\, D_{X,i}^{\alpha_{X,D}}\, K_{X,i}^{\alpha_{X,K}}\, L_{X,i}^{\alpha_{X,L}} \tag{1}$$

$$Z_i = \mathrm{A}_{Z,i}\, D_{Z,i}^{\alpha_{Z,D}}\, K_{Z,i}^{\alpha_{Z,K}}\, L_{Z,i}^{\alpha_{Z,L}} \tag{2}$$

The factor income share parameters are each assumed to be weakly positive with $\alpha_{X,D} + \alpha_{X,K} + \alpha_{X,L} = 1$ and $\alpha_{Z,D} + \alpha_{Z,K} + \alpha_{Z,L} = 1$. A strictly positive land share of factor income in the production of one or both goods, $\alpha_{X,D} > 0$ or $\alpha_{Z,D} > 0$, serves as the source of local congestion. The greater these land factor income shares, the greater the associated congestion force.

Modelling production as Cobb Douglas is done to simplify the analysis. In a generalized framework in which production is modelled as constant elasticity of substitution (CES), congestion forces increase the lower is the elasticity of substitution between land and the other inputs.[2]

Total factor productivity, $\mathrm{A}_{X,i}$ and $\mathrm{A}_{Z,i}$, is assumed to exogenously differ between the two economies. This serves as the first possible source inducing crowding. In the endogenous growth and new economic geography literatures, total factor productivity is typically assumed to increase with the scale of production. Generalizing the present framework to include such increasing returns to scale would be a natural extension. The present purpose, however, is simply to investigate the magnitude of productivity differences that are needed to achieve various levels of crowding rather than to model the source of such variations.

Profit maximization by perfectly competitive firms induces demand such that each of the factors is paid its marginal revenue product. Frictionless intersectoral mobility assures intersectoral factor price equalization within each economy. So the economy-specific returns to land, capital, and labor are respectively given by,

$$\begin{aligned} r_{D,i} &= \alpha_{X,D}\, \mathrm{A}_{X,i} \left(\frac{K_{X,i}}{D_{X,i}}\right)^{\alpha_{X,K}} \left(\frac{L_{X,i}}{D_{X,i}}\right)^{\alpha_{X,L}} \\ &= p_i\, \alpha_{Z,D}\, \mathrm{A}_{Z,i} \left(\frac{K_{Z,i}}{D_{Z,i}}\right)^{\alpha_{Z,K}} \left(\frac{L_{Z,i}}{D_{Z,i}}\right)^{\alpha_{Z,L}} \end{aligned} \tag{3}$$

[2]Cobb Douglas production is consistent with Kaldor's (1961) stylized fact that factor income shares have remained approximately constant across time. For nontraded production, it is consistent with the empirical finding by Thorsnes (1997) that a unitary elasticity of substitution between land and non-land inputs reasonably approximates single-family house production.

$$
\begin{aligned}
r_{K,i} &= \alpha_{X,K}\, \mathrm{A}_{X,i} \left(\frac{D_{X,i}}{K_{X,i}}\right)^{\alpha_{X,D}} \left(\frac{L_{X,i}}{K_{X,i}}\right)^{\alpha_{X,L}} \\
&= p_i\, \alpha_{Z,K}\, \mathrm{A}_{Z,i} \left(\frac{D_{Z,i}}{K_{Z,i}}\right)^{\alpha_{Z,D}} \left(\frac{L_{Z,i}}{K_{Z,i}}\right)^{\alpha_{Z,L}}
\end{aligned} \tag{4}
$$

$$
\begin{aligned}
w_i &= \alpha_{X,L}\, \mathrm{A}_{X,i} \left(\frac{D_{X,i}}{L_{X,i}}\right)^{\alpha_{X,D}} \left(\frac{K_{X,i}}{L_{X,i}}\right)^{\alpha_{X,K}} \\
&= p_i\, \alpha_{Z,L}\, \mathrm{A}_{Z,i} \left(\frac{D_{Z,i}}{L_{Z,i}}\right)^{\alpha_{Z,D}} \left(\frac{K_{Z,i}}{L_{Z,i}}\right)^{\alpha_{Z,K}}
\end{aligned} \tag{5}
$$

Capital is additionally assumed to be perfectly mobile across economies, implying that its return is everywhere the same.

$$
r_{K,s} = r_{K,l} = r_K \tag{6}
$$

Given the present static framework, the capital rent is assumed to be exogenous. In the standard neoclassical dynamic framework, the capital rent would equal the real interest rate plus the rate of capital depreciation.

3.2 Individuals

Individuals derive utility from consumption of four different things: a traded good; a non-traded good; leisure; and quality-of-life.

$$
U_i = \mathrm{u}(x_i, z_i, leisure_i, quality_i) \tag{7}
$$

Quality-of-life is assumed to exogenously differ between the two economies. This serves as the second possible force inducing crowding. More generally, it seems natural to posit that increased crowding from high levels would itself eventually diminish quality-of-life, for instance through increased traffic, pollution, and less public space. On the other hand, increased crowding from low levels may increase quality-of-life, for instance if individuals enjoy interaction with each other.

Henceforth, utility is assumed to be CES with identical, constant elasticity of substitution, σ, among the four utility arguments.[3]

$$U_i = \left(\eta_x \, x_i^{\frac{\sigma-1}{\sigma}} + \eta_z \, z_i^{\frac{\sigma-1}{\sigma}} + \eta_l \, leisure_i^{\frac{\sigma-1}{\sigma}} + \eta_q \, quality_i^{\frac{\sigma-1}{\sigma}} \right)^{\frac{\sigma}{\sigma-1}} \tag{8a}$$

In the special case of a unitary elasticity of substitution, $\sigma = 1$, utility becomes Cobb Douglas:

$$U_i = x_i^{\eta_x} \, z_i^{\eta_z} \, leisure_i^{\eta_l} \, quality_i^{\eta_q} \tag{8b}$$

Regardless of functional form, optimizing behavior by individuals equates the ratio of marginal utility to price *within* each economy. Additionally, individuals' mobility equates utility levels *between* economies.[4]

$$\partial U_i / \partial x_i = \frac{\partial U_i / \partial z_i}{p_i} = \frac{\partial U_i / \partial leisure_i}{w_i} \tag{9}$$

$$U_s = U_l \tag{10}$$

Individuals must each satisfy a budget constraint,

$$x_i + p_i z_i = w_i \, (1 - leisure_i) + nonwage \tag{11}$$

$$nonwage = \frac{\sum_i (r_K \, K_i + r_{D,i} \, D_i)}{\sum_i N_i} \tag{12}$$

Nonwage income is just the per capita sum of all capital and land rents collected in *both* economies, which are then rebated to individuals on a lump-sum basis *regardless of where they live.*

3.3 Closure

In addition to the five profit and utility maximization conditions, several adding up constraints need to be met.

[3]The constant elasticity of substitution need not be identical among the four sources of utility. For instance, there might be one elasticity of substitution between the traded and nontraded goods, a second elasticity between the resulting composite good and leisure, and still another elasticity between the composite traded-nontraded-leisure good and quality-of-life. In all, there are 15 possible CES combinations among four utility arguments: $\binom{4}{2}$ innermost nestings times 2 outer nestings plus 3 possible combinations of pairwise nestings.

[4]The cross-economy equalization of utility *levels* rather than marginal utilities represents an important way in which the present decentralized equilibrium differs from the outcome that would be chosen by a social planner who maximizes mean utility.

For each of the economies, the labor and land factor markets and the nontraded goods market must clear.

$$L_{X,i} + L_{Z,i} = (1 - leisure_i)\, N_i \tag{13}$$

$$D_{X,i} + D_{Z,i} = D_i \tag{14}$$

$$z_i\, N_i = Z_i \tag{15}$$

For the combination of the two economies, the traded goods market must clear and the sum of local populations must equal the exogenously given total population.

$$\sum_i x_i\, N_i = \sum_i X_i \tag{16}$$

$$\sum_i N_i = N \tag{17}$$

The combined optimization conditions, individual budget constraints, local adding up constraints, and global adding up constraints can be reduced to a nonlinear system of eleven equations with eleven unknowns.[5] While this resulting system is sufficiently "well behaved" to postulate the existence of a unique equilibrium across plausible parameterizations, such existence and uniqueness are not proved.

4 Parameterization

The purpose of the present paper is to investigate the direction and relative magnitude of the forces shaping the distribution of population across local areas. In this spirit and in the hope of not misleadingly implying a false level of precision, parameters are set to round values. Such rounding was done in the direction to increase sources of congestion.

[5]With numerous substitutions, the equations are essentially the two first-order conditions, (9), for each locality (4 equations); the factor return equalization conditions, (3) and (5), for each locality (4 equations); the nontraded adding up condition, (15), for each locality (2 equations); and the utility equalization condition, (10) (1 equation). The unknowns are the share of each of labor and land devoted to nontraded-goods production in each locality (4 variables); the share of expenditure devoted to nontraded-goods consumption in each locality (2 variables); leisure in each locality (2 variables); the price of the nontraded good in each locality (2 variables); and the share of total population in the second locality (1 variable).

The numerical results will be presented for two main parameterizations. The need to do so arises from the difficulty in classifying what constitutes a nontraded good. A baseline "narrow" nontraded-good parameterization interprets nontraded goods strictly as housing. But the actual share of individuals' consumption accounted for by nontraded goods and services is likely to be well above this narrow parameterization. For instance, more than 40% of the final retail price of many nominally traded goods may actually pay for nontraded components including transportation, marketing, and retail services (Burstein, Neves, and Rebelo, 2003). And a large portion of such distribution services probably occur in the locality in which the good is consumed. Moreover, many items in individuals' consumption bundle are themselves inherently nontraded (e.g, medical services and education). Hence an alternative, "broad" nontraded-good parameterization interprets nontraded goods to include distribution and other local services.

The size distinction between the two economies is made operational by assuming the small economy's land area is approximately zero. This prevents any feedback from what occurs in the small economy to what occurs in the large economy. In other words, it is solely the productivity and quality-of-life in the large economy that determine the reservation utility and non-wage income of individuals. Small-economy productivity and quality-of-life then determine the small-economy population density that meets the various first-order, factor-return-equalization, and adding-up conditions while allowing individuals in the small economy to achieve the large-economy reservation level of utility. Note that a potential semantic confusion arises because the assumed higher productivity and quality-of-life of the small economy will make it the crowded one. Thus the small economy is also the "big city".

4.1 Base Parameterization (Narrow Nontraded Good Share)

Under the narrow interpretation of nontraded goods, the nontraded consumption share in the large economy is set to 20%. In other words, the utility parameter weighting nontraded goods, η_z, is chosen so that large-economy residents choose to spend 20% of their income on the nontraded good. This is just above the 19% of expenditure accounted for by shelter in the 2000 consumer expenditure survey (U.S. BLS, 2003).

The numerical results are shown for three values of the elasticity of substitution among the sources of utility: unitary, $\sigma = 1$; "intermediate", $\sigma = 0.75$; and "low", $\sigma = 0.50$.

This consumption elasticity is among the most important model parameters. The lower it is, the less willing are individuals in the crowded locality to substitute away from the relatively scarce nontraded good. A unitary parameterization is a helpful benchmark since it implies that a constant share of potential income is spent on each of the three private goods, regardless of relative prices or wages. The intermediate and low parameterizations are respectively consistent with estimates of the elasticity between traded and nontraded goods in Mendoza (1995) and Stockman and Tesar (1995). On the other hand, Burstein, Neves, Rebelo (2003) argue that the elasticity between traded and nontraded goods may be as low as 0.10. If so, congestion forces will be much stronger.

The large-economy leisure share of potential work hours is set to 40%. In other words, η_l is chosen to make this so. A 40% leisure share is consistent with evidence presented in Robinson and Godbey (1997). Numerical results are extremely robust to alternative parameterizations of the leisure share.

Factor income derived from the production of the traded good is assumed to be split among land, capital, and labor on according to $\alpha_{X,D} = 0.10$, $\alpha_{X,K} = 0.25$, and $\alpha_{X,L} = 0.65$. The land share represents a rounding up from the 7% used in Gort, Greenwood, and Rupert (1999). The capital share is identical to that used by them.

Factor income derived from the production of the nontraded good is assumed to be split among land, capital, and labor according to $\alpha_{Z,D} = 0.25$, $\alpha_{Z,K} = 0.10$, and $\alpha_{X,L} = 0.65$. The land share is slightly above an estimate for housing of 22% by Thorsnes (1997) but below an implied estimate of 34% for housing by Jackson, Johnson, and Kaserman (1984). The labor share is assumed to be the same as it is in the production of the traded good so that different rates of TFP growth between the two sectors do not affect labor's share of total factor income.

Finally, the rent on the services of capital goods, r_K, is set to 0.10 representing a 5% real return plus a 5% allowance for depreciation. Table 3 summarizes the base parameterization as well as the alternative parameterization to be discussed presently.

4.2 Alternative Parameterization (Broad Nontraded Good Share)

The main feature distinguishing the alternative parameterization is the much broader interpretation of nontraded goods. Specifically, the nontraded-good share of consumption is set to 40%. This is meant to capture a 20% share for the shelter portion of nontraded goods plus one-quarter of the remaining consumption bundle. The latter, implicit nontraded share can be thought of as capturing local services and the local distribution component of traded-goods consumption. Setting it equal to one-quarter of the non-shelter portion of consumption compares with a two-fifths estimate of the nontraded share of nominally traded goods by Burstein, Neves, and Rebelo (2003). But some portion of such nontraded components probably fall outside the location of final consumption.

Factor income derived from the production of the broadly-interpreted nontraded good is assumed to be split among land, capital, and labor according to $\alpha_{Z,D} = 0.20$, $\alpha_{Z,K} = 0.15$, and $\alpha_{X,L} = 0.65$. The smaller land factor income share compared to the base parameterization reflects that local services and local distribution are likely to be less land intensive than housing. Allowing that the housing component of nontraded goods has the same 25-10-65 split as in the base parameterization, the implicit services/distribution component is produced with a 15-20-65 split of factor income among land, capital and labor.

The division of factor income from the production of the traded good is chosen to achieve an implicit factor share of large-economy *total* consumption that is identical under the two parameterizations. The alternative parameterization is meant to capture a broader conception of nontraded goods. It is *not* meant to capture a more land-intensive total consumption bundle, which unsurprisingly makes crowding more difficult. Under the base parameterization, large-economy combined traded and nontraded consumption expenditures accrue to land, labor, and capital with a 13-22-65 split. For the alternate parameterization, the traded-good factor shares are chosen to achieve the same. Doing so requires that factor income from the production of the traded-good accrue to land, capital, and labor according to $\alpha_{X,D} = 0.083$, $\alpha_{X,K} = 0.267$, and $\alpha_{X,L} = 0.65$.

5 Numerical Results

The present section shows that moderate increases in productivity or in quality-of-life can cause large increases in crowdedness. As productivity-driven crowdedness increases, individuals increase their consumption of traded goods but decrease their consumption of nontraded goods. As quality-of-life-driven crowdedness increases, individuals decrease their consumption of both traded and nontraded goods. With either source of crowding, nontraded goods prices are substantially higher in the crowded economy. Land rents in the crowded economy are even higher.

A last subsection illustrates an important implication of the model: technological progress can induce substantial migration towards localities with high quality-of-life. Technological progress, in the form of rising productivity in the production of traded or nontraded goods, causes individuals to increase their valuation of quality-of-life. When the elasticity of substitution among the sources of utility is less than one, an increase in the crowdedness of high quality-of-life localities is required to maintain general equilibrium.

5.1 Productivity-Driven Crowding

A first set of numerical experiments shows the degree of crowdedness that results as traded-good TFP in the small economy increasingly exceeds its level in the large economy. That is, the experiments show small-economy population density and remaining endogenous variables as $A_{X,s}$ increasingly exceeds $A_{X,l}$.

From a theoretical perspective, whether higher productivity causes higher population density is ambiguous. On the one hand, higher productivity allows firms to pay higher wages which in turn attracts population. But higher traded-good productivity also raises the opportunity cost of diverting land to production of the nontraded good. As the land share of traded-good factor income goes to one, higher traded good productivity will "crowd out" population.

Numerical results, however, establish that such crowding out occurs only when labor's share of factor income is unrealistically small. Specifically, as long as labor's share is greater than 20%, experiments across a very wide range of parameterizations all find that increasing small-economy traded-good productivity increases small-economy population. For many parameter combinations, the labor-share minimum threshold is considerably lower. Moreover, when crowding out does occur, often it is only a local result. That is, for parameter combinations at which $\mathrm{d}L_s/\mathrm{d}A_s$ evaluated at $A_{X,s}$ equal to $A_{X,l}$ is negative, usually $\mathrm{d}L_s/\mathrm{d}A_s$ becomes positive for $A_{X,s}$ above some higher threshold.

Figure 1 Panel A shows the ratio of small-economy to large-economy traded productivity needed to attain various levels of crowdedness under the base parameterization. For the small economy to have an equilibrium population density 8 times that of the large economy, its traded good productivity must be from 1.44 to 1.51 times that of the large economy. The lower value, 1.44, is the required ratio when individuals are relatively willing to substitute away from the nontraded good (σ equal to 1). The upper value, 1.51, is the required ratio when individuals are relatively reluctant to substitute away from the nontraded good (σ equal to 1/2). To achieve a relative population density of 32, small-economy traded good productivity must be from 1.83 (σ equal to 1) to 2.08 (σ equal to 1/2) times that of the large economy.

The magnitudes of the required productivity variations are quite plausible. Similar-magnitude productivity variations are observed across OECD nations. For example, U.S. total factor productivity in 1988 was 1.52 that of Japan and 1.99 that of Turkey (Hall and Jones, 1999).

For localities, productivity differences seem intuitive via a number of theoretical mechanisms including locational advantages (Rappaport and Sachs, 2003), local industry economies-of-scale (Marshall, 1890), functional specialization (Duranton and Puga, 2001), and general knowledge spillovers (Jacobs, 1969). Of course, some of these mechanisms imply a causal relationship from population density (and also total population) to productivity. Such endogenous productivity easily nests within the current modeling framework.

The remaining panels of Figure 1 show how the main other endogenous variables vary with productivity-driven crowding. The left columns of Table 4 contain a summary.

Increases in small-economy traded-good productivity cause an increase in small-economy wages (Panel B). This is the transmission mechanism causing the increase in population density. Note that the wage increase is real in the sense that it is denominated in terms of the traded good. But it is also nominal in the sense that it does not reflect the higher relative price of nontraded goods. At a small-economy relative population density of 8 and assuming an intermediate consumption elasticity, small economy wages are 27% higher than large economy ones. At a relative population density of 32, they are 50% higher. The elasticity of wages with respect to population density ranges from 0.09 to 0.20 depending on the relative population density at which is evaluated and the consumption elasticity of substitution. This compares favorably with the wage elasticity estimates of 0.08 and 0.14.

Unsurprisingly, land prices increase quite rapidly with crowding. Nontraded-good prices also increase, but by much less than do land prices. At a small-economy relative population density of 8 and again assuming an intermediate consumption elasticity, small-economy land prices are 10.5 times that of large-economy ones (Panel C). But small economy nontraded-good prices are "just" 2.1 times large-economy ones (Panel D). At a relative population density of 32, small-economy land prices are 51 times large-economy ones and small-economy nontraded-good prices are 3.5 times large-economy ones. The elasticity of small-economy land prices with respect to population density ranges from 1.09 to 1.24 depending on relative population density and the consumption elasticity of substitution. The corresponding elasticity of small-economy nontraded goods prices ranges from 0.33 to 0.44. The latter compares favorably with estimated elasticities of housing expenditures of 0.20 and 0.40.

The much higher sensitivity to crowdedness of land prices compared to nontraded-goods prices arises for two reasons. First is that land is just one of three production inputs. The price of the labor input has also increased but by a comparatively small amount. And by assumption, the price of the capital input has remained constant. Second, the unitary elasticity associated with Cobb-Douglas production allows for a large substitution away from small-economy land in producing the nontraded good. At a relative population density of 8, the amount of land input per nontraded good in the small economy is 0.20 that in the large economy (i.e., $(D_{Z,s}/Z_s)/(D_{Z,l}/Z_l)$). At a relative population density of 32, the same ratio is 0.07.

Individuals in the small economy achieve the large-economy level of utility by increasing their relative consumption of traded goods but decreasing their relative consumption of nontraded goods and leisure. At a relative population density of 8 and intermediate consumption elasticity, small economy residents consume 15% more traded goods but 34% less nontraded goods and 4% less leisure than their counterparts in the large economy. At a relative population density of 32, they consume 27% more traded goods but 50% less nontraded goods and 6% less leisure.

The numerical results from the base parameterization thus suggest that moderate increases in productivity can cause large increases in crowdedness. As productivity-driven crowdedness increases, individuals receive higher wages which allows them to increase their consumption of traded goods. But they also must pay much higher prices for nontraded goods leading to a fairly large decrease in their consumption of them. The nontraded goods that crowded-economy residents do consume are much less intensive in land than uncrowded-economy nontraded goods. Finally, crowded-economy residents choose to work longer hours than do uncrowded-economy residents.

The alternate, broad-nontraded-good-share, parameterization implies identical qualitative results and moderately-larger-magnitude quantitative results. With an intermediate consumption elasticity of substitution, achieving 8-times and 32-times relative population density in the small economy requires traded-good productivity that is respectively 74% and 150% above that in the large economy (Table 4). The elasticity of wages and of land rents with respect to density are also somewhat higher than under the base calibration.

Two main reasons account for the different quantitative responses under the alternate calibration. First is that the small economy's productivity advantage applies to a smaller portion of individuals' consumption bundle. Under the base calibration, the small economy is more productive than the large one in producing a good that accounts for 80% of consumption expenditures at the large-economy price vector. Under the alternate calibration, the productivity advantage applies to a good that accounts for only 60% of such expenditures. Unsurprisingly, a given increase in productivity causes less crowding.

A second reason for the different quantitative response under the alternate calibration is that the implicit land share of total consumption expenditures via the nontraded good is higher. By assumption, the implicit land share of total consumption at the large-economy price vector is identical under the two parameterizations. But the share of total consumption accruing to land via the nontraded good rises from 5% to 8% (at the large-economy price vector). Numerical results show that endogenous congestion increases as this implicit land nontraded share increases.

5.2 Quality-of-Life-Driven Crowding

A second set of numerical experiments shows the degree of crowdedness that results as quality-of-life in the small economy increasingly exceeds its level in the large economy. That is, the experiments show small-economy population density and remaining endogenous variables as $quality_s$ increasingly exceeds $quality_l$.

Like utility, quality-of-life is an inherently ordinal concept. To give a cardinal interpretation, differences between small-economy and large-economy quality-of-life will be discussed in terms of their equivalent and compensating variations. Let $\mathrm{e}(w, p, quality; U)$ be the minimum "expenditure" needed to achieve utility U for a given wage-price-quality vector. For present purposes, this expenditure is defined to include the opportunity cost of leisure. So,

$$\mathrm{e}\left(w, p, quality; U\right) \equiv \mathrm{Min}\left(x + p\,z + w\,leisure\right) \text{ s.t. } u\left(x, z, leisure, quality\right) = U$$

The equivalent variation of small-economy versus large-economy quality-of-life will be defined as the negative lump-sum transfer to large-economy individuals that leaves their utility unchanged when they enjoy small-economy quality-of-life while still facing large-economy prices.

$$EV \equiv \mathrm{e}(w_l, p_l, quality_l; U_l) - \mathrm{e}(w_l, p_l, quality_s; U_l)$$

The compensating variation of small-economy versus large-economy quality-of-life will be defined as the lump-sum transfer to small-economy individuals that leaves their utility unchanged when they enjoy large-economy quality-of-life while still facing small-economy prices.

$$CV \equiv \mathrm{e}(w_s, p_s, quality_l; U_s) - \mathrm{e}(w_s, p_s, quality_s; U_s)$$

Both EV and CV are defined to be positive when quality-of-life is higher in the small economy. An equilibrium condition of the present model is that $U_l = U_s$. So in practice, the only distinction between EV and CV is the wage-price vector at which quality-of-life is compared.

To give a more intuitive interpretation of the magnitude of differences in quality-of-life, EV, will be normalized by actual large-economy expenditure, and CV will be normalized by actual small-economy expenditure. Note that such actual expenditures do not include the opportunity cost of leisure.

$$\widetilde{EV} \equiv EV / \left(x_l + p_l z_l\right)$$

$$\widetilde{CV} \equiv CV / \left(x_s + p_s z_s\right)$$

The higher is quality-of-life in the small economy relative to the large economy, the more crowded the small economy will be. Figure 2 Panel A shows the relative population density of the small economy as the normalized equivalent variation increases from zero under the base calibration. For the small economy to have an equilibrium population density that is 8 times the level of the large economy, its quality-of-life must exceed that of the large economy by a normalized equivalent variation that ranges from 21% to 22%. The lower value holds when individuals are relatively willing to substitute among the various sources of utility. The higher value, when they are not. To achieve a relative population density of

32, small-economy quality-of-life must exceed large-economy quality-of-life by a normalized equivalent variation that ranges from 32% to 35%.

The magnitudes of the required differences are quite plausible. Among the non-former-communist European Union nations, per capita real consumption in 2000 varied by a multiplicative factor of 1.76 (Heston, Summers, and Aten, 2002). For example, per capita consumption in Britain was 1.16 that in France, 1.34 that in Belgium, and 1.48 that in Sweden. Even so, the lack of significant internal migration pressures among these nations suggests that non-consumption components of utility are contributing to an equating of utility levels across them.

The remaining panels of Figure 2 show how the main other endogenous variables vary with quality-of-life-driven crowding. The right columns of Table 4 contain a summary.

Increases in small-economy quality-of-life are associated with decreases in small-economy wages but increases in small-economy land prices and nontraded-good prices (Panes B, C, and D). The intuition is the same as that underlying the compensating wage differential literature (Rosen, 1979; Roback, 1982; Blomquist, Berger, and Hoehn, 1988; Gyourko and Tracy, 1989, 1991). If wages and prices were identical between the two economies, indviduals in the small economy would enjoy a higher level of utility due to the higher quality-of-life. Hence wages must be lower or nontraded-good prices must be higher in the small economy. For firms, the equilibrium requirement of equal profitability across the two economies (implicitly captured by the equalization of capital rents) implies that higher land prices must be offset by lower wages. The higher population density of the small economy along with a complementary high intensity of capital per unit land are the mechanisms by which the equilibrium wage-price vector is realized.

At a small-economy relative population density of 8 and an intermediate consumption elasticity, small-economy wages are 25% lower than large-economy ones. Small-economy land prices are 6.2 times large economy ones. And small-economy nontraded goods prices are 32% above large-economy ones. At a small-economy relative population density of 32, the corresponding wage discount, land price ratio, and nontraded good price premium are 37%, 21.1, and 58%. At both relative densities, the land-price ratio and nontraded-goods-price premium are below what they would be if the crowding were caused by a small-economy productivity advantage. The reason is that when crowding is driven by productivity, small-economy residents are wealthier than their large-economy counterparts (in terms of their purchasing power of traded goods). But when crowding is driven by quality-of-life, small-economy residents are poorer. Correspondingly, the elasticities of land prices and nontraded-good prices with respect to population density are lower when crowding is driven by quality-of-life.

Quality-of-life-driven crowding implies a negative elasticity of wages with respect to population density. This sharply contrasts with positive estimates. One possible interpretation is that observed crowding derives primarily from productivity differences rather than quality-of-life ones. Another is that high-human-capital individuals disproportionately sort into high-quality-of-life localities (Benabou, 1993, 1996). Such sorting would obviously drive up the elasticity of mean local wages with respect to crowding. It would also drive up the elasticity of low-human-capital individual's wages with respect to crowding in order to compensate them for higher nontraded-goods prices.

The higher quality-of-life in the small economy allows its residents to achieve the large-economy utility while consuming less of both traded and nontraded goods (Panels E and F). Which residents consume more leisure depends on the elasticity of substitution among the sources of utility. With a unitary or intermediate consumption elasticity, leisure is higher in the small economy. But with a low consumption elasticity, leisure is lower in the small economy (Panel G). The ambiguity of the effect of quality-of-life-driven crowding on leisure consumption reflects two competing forces. On the one hand, lower small-economy wages lower the opportunity cost of leisure. On the other hand, lower small-economy consumption of traded and nontraded goods increases their marginal utility. When the elasticity of substitution is high, the former force dominates. When it is low, the latter one does.

The numerical results from the base parameterization suggest that moderate increases in quality-of-life can cause large increases in crowdedness. As quality-of-life-driven crowdedness increases, individuals accept lower wages and pay higher prices for nontraded goods. In response, they cut their consumption of both traded and nontraded goods. As with productivity-driven crowding, the nontraded goods that crowded-economy residents do consume are much less intensive in land than uncrowded-economy nontraded goods. And depending on the elasticity of substitution among the sources of utility, crowded-economy residents may choose to consume either more or less leisure than do residents in the uncrowded economy.

The alternate, broad-nontraded-good-share, parameterization implies identical qualitative results and very similar quantitative results. Small-economy wages, nontraded-goods consumption, and traded-goods consumption fall by slightly less. Small-economy land prices rise by slightly more. And nontraded-goods prices rise by slightly less. But the quantitative differences between the two parameterizations are much smaller than when crowdedness is driven by productivity.

5.3 Technological Progress and the Increasing Importance of Quality-of-Life

The previous subsection looked at the quality-of-life differences needed to achieve various degrees of crowdedness. This subsection shows that broad-based technological progress can induce migration towards localities with high quality-of-life. The underlying mechanism is closely related to the Harrod-Ballasa-Samuelson effect, in which faster growth in traded-goods production causes a rise in the relative price of nontraded goods (Harrod, 1933; Balassa, 1964; Samuelson, 1964). In the present model, an increase in traded-goods productivity also causes a rise in the relative price of quality-of-life. With a unitary elasticity of substitution, the resulting adjustment to wages and nontraded goods prices that maintains equilibrium in the large economy will also continue to equate utility levels between it and the high-quality-of-life small economy. But with an elasticity of substitution that is less than one, only an increase in the relative crowdedness of the small economy allows nontraded-goods prices there to rise sufficiently to equate utility levels.

The numerical exercise assumes that traded-good TFP in both economies increases at a 1.5% annual rate. This is slightly faster than can be justified empirically. But for present purposes, what is more important is that the assumed TFP growth rate along with the 25% capital share under the base calibration implies that labor productivity grows at 2% per year. The latter approximately matches the U.S. rate of labor productivity growth over the period 1959 to 1998 and is at the low end of estimates of the current trend rate of labor productivity growth (Jorgenson and Stiroh, 2000; Jorgenson, Ho, and Stiroh 2002; Oliner and Sichel, 2000, 2002; Basu et. al., 2003).

Nontraded-good TFP in both economies is assumed to remain constant. That technological progress has increased productivity faster in the traded than in the nontraded sector is intuitive. For example, the process of building a house has evolved much less over the past

50 years than the process of building a car. At the same time, there definitely has been TFP growth in the production of nontraded goods. Even for housing, evidence suggests that TFP growth may be as high as two-fifths of TFP growth for traded goods (Gort, Greenwood, and Rupert, 1999). But any such technological progress primarily affects investment in housing *stock*. More important for present purposes is the production of housing *services* from such stock. There is less reason to suppose this has changed. Moreover, the assumption of zero technological progress is helpful in conveying the intuition underlying relative price changes. Alternatively assuming positive technological progress in the production of nontraded goods reinforces the rise in the valuation of quality-of-life and any resulting migration.

The increased valuation of quality-of-life parallels increased valuations of nontraded goods and leisure. Technological progress affects prices, wages, and consumption choices in both the large and small economies. Since the small-economy equilibrium is based on the large-economy one, it makes sense to start by discussing what is going on in the large economy.

The increase in traded-good TFP causes a greater than proportional increase in large-economy wages. The difference is due to capital deepening. In particular, the 1.5% rate of TFP increase is equivalent to simultaneous labor-augmenting and land-augmenting technological progress of 2% each. Assuming a constant supply of both factors, the returns to each will also increase at 2% per year. Figure 3 Panel A shows this 2%-growth wage path. With a unitary elasticity of substitution, it is indeed consistent with constant supplied labor (Panel B). But with a lower elasticity of substitution, individuals seek to use some of their increased wealth to increase their consumption of leisure. As a result, supplied labor decreases and so wages rise at slightly more than 2% per year.

The key property of a unitary elasticity of substitution is that individuals devote a constant share of their expenditure to each of the sources of utility. Under the present scenario, their income increases by 2% per year. This decomposes into a 2% increase in both wages and land rents multiplied by a constant amount supplied of each plus a constant capital rent multiplied by a 2% increase in capital supplied to both the traded- and nontraded-good sectors. Since wages are just the opportunity cost of leisure, constant leisure choice corresponds to a 2% per year increase in effective expenditure on leisure and hence a constant share. Similarly, large-economy individuals continually choose to devote 20% of their explicit consumption expenditure to the nontraded good (Panel C).

The constant nontraded-goods expenditure share decomposes into a slight increase in nontraded consumption multiplying an increase in the price of nontraded goods that is rising at slightly less than 2% per year (Figure 3 Panel A). The increase in nontraded-goods consumption follows from (4). To see this, suppose instead that the increase in nontraded expenditure came solely from a rising nontraded price. But this would counterfactually imply a proportional increase in the rent paid to capital used in the nontraded sector. Instead, the lower marginal product of capital associated with a 2% per year increase in capital supplied to the nontraded sector exactly offsets a 1.8% per year rise in the nontraded-good price so that the capital rent remains at its assumed 10% level. Real nontraded-goods consumption must therefore grow at 0.2% per year.

As the consumption elasticity of substitution decreases from one, large-economy individuals increasingly desire to use their rising wealth to purchase nontraded goods and leisure. With an intermediate elasticity, leisure increases from the assumed 40% of potential work hours in year 0 to 42% in year 20 and to 45% in year 50. With a low elasticity, it increases to 44% in year 20 and to 50% in year 50 (Panel B). Similarly, with an intermediate elasticity, the share of expenditures on nontraded goods increases from the assumed 20% in year 0 to 21.5% in year 20 and to 24% in year 50. With a low elasticity, the nontraded expenditure share increases to 23% in year 20 and to 28.0% in year 50 (Panel C). With both the intermediate and low elasticities, the nontraded price actually increases by slightly less than with a unitary elasticity. This is counterintuitive given the increased relative demand for the nontraded good. It should be understood as a general equilibrium effect. The shifting of land, labor, and capital into the nontraded sector causes the nontraded supply curve to shift out by more than the outward shift of the nontraded demand curve.

Large-economy individuals similarly desire to increase their consumption of quality-of-life. But the only way to do so is to move to the small economy. In year zero, population density in the small economy is *assumed* to be 4 times that in the large economy (Panel D). Depending on the consumption elasticity of substitution, the normalized equivalent variation needed to achieve this degree of crowding ranges from 0.142 to 0.154 (Panel E). With a unitary elasticity of substitution, no actual movement takes place. Instead, the "price" of living in the small economy rises without any migration at exactly the right rate to offset the increased valuation of the quality-of-life difference. But with a lower elasticity of substitution, the increase in price at the initial population density ratio is not sufficient to offset the increased valuation.

In the present example, individuals with a unitary elasticity of substitution increase their valuation of the small economy's higher quality-of-life at a 2% annual rate. Without any migration, wages and non-wage income in both economies also rise at 2% per year. This implies that the amount by which large-economy wages exceed small-economy wages rises at 2% per year. Similarly, the ratio of nontraded-good prices in the small relative to the large economy remains constant (Panel F). Hence the amount by which small economy nontraded-goods prices exceed large-economy ones rises at 1.8% per year. And since large-economy nontraded consumption is growing at 0.2% per year, the difference in cost between the two economies for purchasing the contemporary large-economy level of nontraded consumption increases at 2% per year. Thus, there is no incentive to migrate. Note that the equivalent and compensating variations respectively normalized by large-economy and small-economy income remain constant over time. Small-economy individuals are effectively allocating a constant share of their expenditure to quality-of-life. This is exactly what one would expect with Cobb Douglas utility.

The lower is the consumption elasticity of substitution, the more rapidly individuals increase their valuation of the small economy's higher quality-of-life. With an intermediate consumption elasticity, the absolute equivalent and compensating variations initially increase at 2.3% per year. With a low consumption elasticity, they initially increase at 2.9% per year. The respective initial rates of small-economy population growth needed to bring about an offsetting increase in the opportunity cost of living in the small economy are 0.6% and 1.5% per year. This population growth puts some downward pressure on the TFP-driven increase in wages so that the relative wage between the two economies falls (not shown). Large-economy individuals' valuation of the quality-of-life differential rises more quickly than does their wage. As a result, their normalized equivalent variation increases over time (Panel E). Small-economy residents' normalized compensating variation rises even more rapidly (not shown).

A consumption elasticity less than one can imply substantial cumulative migration into the small economy. By assumption, initial small-economy to large-economy population density is 4. With an intermediate elasticity, small-economy relative population density increases to 4.5 after 20 years and to 5.4 after 50 years. With a low elasticity, it increases to 5.5 after 20 years and to 9.1 after 50 years. Under the alternative, broad, parameterization, the flow into the small economy is similar in magnitude.

Any migration into the small economy causes a small increase in the price of the nontraded good there relative to the price of the nontraded good in the large economy (Panel F). This price increase is on top of the increase in the large-economy price of the nontraded good relative to the traded good. With an intermediate elasticity, the faster nontraded-good price growth in the small economy is approximately 0.08% per year. With a low elasticity, it is approximately 0.21% per year. The return to land owned in the small economy grows substantially faster than the return to land owned in the large economy. Again, this is on top of the steadily increasing return to the latter. With an intermediate elasticity, the price of land services grows 0.50% per year quicker in the small economy. With a low elasticity, it grows 1.4% per year faster.

A number of empirical regularities suggest that the elasticity of substitution among different sources of utility is indeed less than one. First is that time devoted to leisure has been steadily increasing over time. This would follow from an elasticity of substitution with goods consumption that is less than one. The share of individuals' post-formal-education lives devoted to work fell steeply over the twentieth century. For employed men, average weekly working hours fell from 55 in 1910 down to 48 in 1920 and then down to 40 in 1940 (Costa, 2000). Since then, a continuing decrease in time devoted to work has taken the form of increased vacation, holidays, sick days, personal leave, and early retirement. For example, labor force participation among men older than 64 fell from 58% in 1930 to less than 20% in 1990 (Costa, 1998).[6] The American's Use of Time Project (Robinson and Godbey, 1997) also finds that leisure consumption is trending up. From 1965 to 1985, hours per week of free time for employed men aged 18 to 64 increased from 33.0 hours in 1965 to 36.4 hours in 1985. For employed women, the comparable increase was from 27.2 hours to 34.0 hours. For all men and women aged 55 to 64 (i.e., regardless of employment status), average weekly free hours increased from 34.0 to 45.6 over the same period.

The share of individuals' consumption expenditure devoted to housing has also been steadily increasing over time. As with leisure, this would arise from slower-than-average technological progress plus an elasticity of substitution with other forms of consumption

[6] The increase in female labor force participation during the twentieth century almost certainly represents a substitution of market for home production rather than any decrease in leisure (Greenwood, Seshadri, and Yorukoglu, 2003).

that is less than one. Estimates in Lebergott (1993) show that the share of U.S. personal consumption expenditure devoted to housing rose from 7.8% in 1900 to 11.4% in 1950 and then further to 16.3% in 1980. More recent data from the Consumer Expenditure Survey shows that the shelter share of consumption rose from 15.9% in 1984 to 19.3% in 2003 (United States Bureau of Labor Statistics, 2004).

Recreation is still another good that has experienced an increase in expenditure share but probably slower-than-average technological progress. Costa (1998) estimates that individuals' average share of expenditures devoted to recreation has tripled from 2% in the late 1880's to 6% in 1991.

If the elasticity of substitution for each of these several types of low-TFP-growth consumption goods with high-TFP-growth consumption goods is indeed less than one, it seems natural to think that the elasticity of substitution between quality-of-life and goods consumption is also less than one. A more direct piece of evidence is the estimate by Costa and Kahn (2003) that the price for obtaining San Francisco's climate over Chicago's climate grew at an 8.8% annual real rate over the period 1970 to 1990. Such extremely high growth of a quality-of-life compensating differential suggests an elasticity of substitution that is well below one half. Rappaport (2003) finds empirical support for the implied migration towards high-quality-of-life localities. He argues that the shifting of the United States' population toward locations with mild weather is driven primarily by an increased valuation of quality-of-life rather than by the invention of air-conditioning or by increased elderly mobility.

6 Conclusions

A simple general equilibrium model is able to account for much of the observed variation in population density across U.S. localities. Moderate increases in local productivity or in local quality-of-life can cause large increases in local crowdedness. Thus some cities are especially crowded because they have either high productivity or high quality-of-life.

The model implies that if the elasticity of substitution among the sources of utility is less than one, technological progress causes individuals to migrate to high-quality-of-life localities. Over time, the resulting shift in population can be substantial. Paralleling such migration, individuals increase their consumption of leisure and the share of their expenditures they devote to consumption. Empirical evidence confirms all three trends.

Concluding that crowded cities are that way because they have high productivity or high quality-of-life begs the question, what is the source of their high productivity or high quality-of-life. Of course, identifying the determinants of local productivity and quality-of-life is the subject of substantial empirical research. The present paper contributes to this research agenda by showing that empirically identifying the determinants of local population density is addressing essentially the same question.

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Table 1: Variations in Population Density

Rankings by population density (persons per square mile) in 2000 of continental U.S. local areas with population in 2000 of at least 100,000

A. Metropolitan Areas

CMSA/MSA's with populaton 100,000+

1	New York--Northern New Jersey--Long Island, NY--NJ--CT--PA CMSA	2,029
2	Chicago--Gary--Kenosha, IL--IN--WI CMSA	1,322
3	Miami--Fort Lauderdale, FL CMSA	1,230
4	Philadelphia--Wilmington--Atlantic City, PA--NJ--DE--MD CMSA	1,043
5	Providence--Fall River--Warwick, RI--MA MSA	1,042
6	Boston--Worcester--Lawrence, MA--NH--ME--CT CMSA	1,034
7	San Francisco--Oakland--San Jose, CA CMSA	955
8	Milwaukee--Racine, WI CMSA	942
9	Tampa--St. Petersburg--Clearwater, FL MSA	938
10	Detroit--Ann Arbor--Flint, MI CMSA	831
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250	Las Vegas, NV--AZ MSA	40
251	Grand Junction, CO MSA	35
252	Duluth--Superior, MN--WI MSA	32
253	Yuma, AZ MSA	29
254	Flagstaff, AZ--UT MSA	5

B. Urbanized Areas

UA's with populaton 100,000+

1	Los Angeles--Long Beach--Santa Ana, CA UA	7,068
2	San Francisco--Oakland, CA UA	7,004
3	San Jose, CA UA	5,914
4	New York--Newark, NY--NJ--CT UA	5,309
5	New Orleans, LA UA	5,102
6	Vallejo, CA UA	4,682
7	Las Vegas, NV UA	4,597
8	Oxnard, CA UA	4,460
9	Miami, FL UA	4,407
10	Fairfield, CA UA	4,356
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251	South Lyon--Howell--Brighton, MI UA	1,117
252	Asheville, NC UA	1,072
253	Spartanburg, SC UA	1,055
254	Hickory, NC UA	891
255	Barnstable Town, MA UA	852

C. Counties

Counties with populaton 100,000+

1	New York County, NY	66,940
2	Kings County, NY	34,916
3	Bronx County, NY	31,709
4	Queens County, NY	20,409
5	San Francisco County, CA	16,634
6	Hudson County, NJ	13,044
7	Suffolk County, MA	11,788
8	Philadelphia County, PA	11,234
9	District of Columbia	9,316
10	Richmond County, NM	7,588
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506	Yavapai County, AZ	21
507	Douglas County, OR	20
508	Cochise County, AZ	19
509	Mohave County, AZ	12
510	Coconino County, AZ	6

D. Municipalities

Places with populaton 100,000+

1	New York, NY	26,403
2	Paterson, NJ	17,675
3	San Francisco, CA	16,634
4	Jersey City, NJ	16,094
5	Cambridge, MA	15,766
6	Daly City, CA	13,704
7	Chicago, IL	12,750
8	Santa Ana, CA	12,452
9	Inglewood, CA	12,324
10	Boston, MA	12,166
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233	Athens-Clarke, GA	916
234	Oklahoma City, OK	909
235	Peoria, AZ	834
236	Augusta-Richmond, GA	784
237	Chesapeake, VA	585

Table 2: Variations in Wages and House Prices

Rankings based on selected 2000 statistics for continental U.S. urbanized areas with population in 2000 of 100,000 or greater. ε gives the elasticity with population density. R^2 gives the share of variation accounted for in the corresponding regression of the dependent variable on population density and a constant.

A. Wage and Salary, All Workers

median annual wage and salary earnings for pop. 16+ with positive earnings (ε = 0.08; R^2 = 0.02)	
1 Concord, CA UA	37,667
2 Mission Viejo, CA UA	35,674
3 San Rafael--Novato, CA UA	35,167
4 Thousand Oaks, CA UA	35,131
5 San Jose, CA UA	33,373
6 Santa Clarita, CA UA	32,294
7 Simi Valley, CA UA	31,647
8 Bridgeport--Stamford, CT--NY UA	31,534
9 Washington, DC--VA--MD UA	31,448
10 South Lyon--Howell--Brighton, MI UA	31,382
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251 Gainesville, FL UA	13,394
252 Athens-Clarke County, GA UA	12,498
253 Brownsville, TX UA	12,467
254 McAllen, TX UA	12,122
255 College Station--Bryan, TX UA	10,663

B. Wage and Salary, Homogeneous Workers

median annual wages of registered nurses (ε = 0.14; R^2 = 0.21)*	
1 San Francisco--Oakland--San Jose, CA CMSA	$63,602
2 Bakersfield, CA MSA	$56,080
3 Sacramento--Yolo, CA CMSA	$55,604
4 Fresno, CA MSA	$54,530
5 Los Angeles--Riverside--Orange County, CA CMSA	$53,990
6 New York--Northern New Jersey--Long Island, NY--NJ--CT--PA CMSA	$53,653
7 Washington--Baltimore, DC--MD--VA--WV CMSA	$53,435
8 Cumberland, MD--WV MSA	$52,850
9 Seattle--Tacoma--Bremerton, WA CMSA	$52,468
10 Yuba City, CA MSA	$51,910
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225 Davenport--Moline--Rock Island, IA--IL MSA	$32,870
226 Waterloo--Cedar Falls, IA MSA	$32,130
227 State College, PA MSA	$30,560
228 Wheeling, WV--OH MSA	$29,240
229 Terre Haute, IN MSA	$29,170

*Elasticity is for CMSA/MSA median wages with respect to urbanized area population density. 25 missing values.

C. Housing Expenditure, Renters

median monthly housing rent, including utilites (ε = 0.20; R^2 = 0.13)	
1 San Jose, CA UA	1,118
2 Thousand Oaks, CA UA	1,115
3 San Rafael--Novato, CA UA	1,092
4 Mission Viejo, CA UA	1,052
5 Simi Valley, CA UA	990
6 Concord, CA UA	982
7 Santa Cruz, CA UA	925
8 Santa Clarita, CA UA	911
9 Santa Barbara, CA UA	878
10 San Francisco--Oakland, CA UA	855
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251 Fort Smith, AR--OK UA	394
252 Huntington, WV--KY--OH UA	390
253 McAllen, TX UA	379
254 Brownsville, TX UA	376
255 Odessa, TX UA	375

D. Housing Expenditure, Owners

median self-assessed value of owner-occupied housing units (ε = 0.40; R^2 = 0.14)	
1 San Rafael--Novato, CA UA	482,977
2 Santa Barbara, CA UA	434,593
3 San Jose, CA UA	414,430
4 Santa Cruz, CA UA	371,899
5 Concord, CA UA	355,509
6 Seaside--Monterey--Marina, CA UA	353,067
7 San Francisco--Oakland, CA UA	324,952
8 Thousand Oaks, CA UA	310,533
9 Mission Viejo, CA UA	297,521
10 Boulder, CO UA	282,781
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251 Port Arthur, TX UA	50,878
252 Harlingen, TX UA	50,287
253 McAllen, TX UA	49,461
254 Brownsville, TX UA	48,730
255 Odessa, TX UA	44,721

E. Commuting Time

median one-way travel time to work in minutes (ε = 1.56; R^2 = 0.04)*	
1 New York--Northern New Jersey--Long Island, NY--N	30.4
2 Washington--Baltimore, DC--MD--VA--WV CMSA	30.1
3 Atlanta, GA MSA	29.4
4 Chicago--Gary--Kenosha, IL--IN--WI CMSA	28.6
5 Miami--Fort Lauderdale, FL CMSA	26.4
6 Houston--Galveston--Brazoria, TX CMSA	25.8
7 San Francisco--Oakland--San Jose, CA CMSA	24.8
8 Los Angeles--Riverside--Orange County, CA CMSA	24.4
9 Orlando, FL MSA	24.3
10 Dallas--Fort Worth, TX CMSA	24.3
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249 Rochester, MN MSA	14.8
250 Fargo--Moorhead, ND--MN MSA	14.8
251 Waterloo--Cedar Falls, IA MSA	14.7
252 Sheboygan, WI MSA	14.6
253 Flagstaff, AZ--UT MSA	14.6

*Elasticity is for CMSA/MSA commute time with respect to urbanized area population density. 1 missing value.

F. Housing Type

percent of occupied housing units in structures with 20+ units (ε = 0.70; R^2 = 0.29)	
1 New York--Newark, NY--NJ--CT UA	27.6%
2 Miami, FL UA	25.2%
3 Fargo, ND--MN UA	21.9%
4 Houston, TX UA	18.8%
5 Boulder, CO UA	17.4%
6 San Francisco--Oakland, CA UA	17.1%
7 Minneapolis--St. Paul, MN UA	17.1%
8 Austin, TX UA	17.0%
9 Los Angeles--Long Beach--Santa Ana, CA UA	16.8%
10 Madison, WI UA	16.5%
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251 Gastonia, NC UA	2.7%
252 Clarksville, TN--KY UA	2.6%
253 Barnstable Town, MA UA	2.6%
254 Fayetteville, NC UA	2.0%
255 Brooksville, FL UA	1.1%

Table 3: Base and Alternative Parameterizations

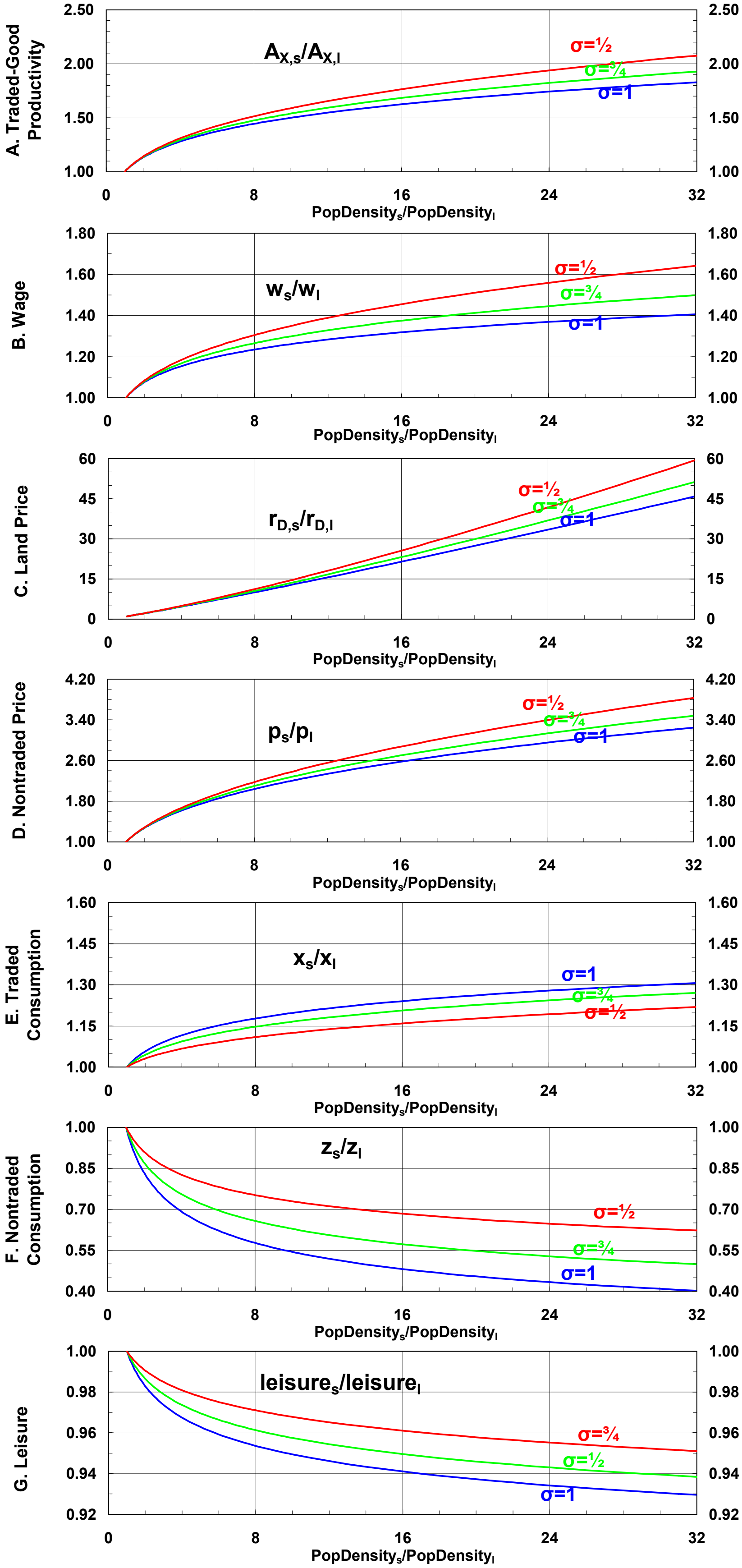
	Base (Narrow Nontraded Good)	Alternative (Broad Nontraded Good)
Nontraded Production Factor Income		
Land, Capital, Labor Shares		
($\alpha_{X,D}$, $\alpha_{X,K}$, $\alpha_{X,L}$)	25%, 10%, 65%	20%, 15%, 65%
Traded Production Factor Income		
Land, Capital, Labor Shares		
($\alpha_{X,D}$, $\alpha_{X,K}$, $\alpha_{X,L}$)	10%, 25%, 65%	8.3%, 26.7%, 65%
Large-Economy Consumption Expenditure		
Traded, Nontraded shares		
(determines η_X and η_Z)	80%, 20%	60%, 40%
Land, Capital, Labor implicit shares	13%, 22%, 65%	13%, 22%, 65%
via Traded Good	8%, 20%, 52%	5%, 16%, 39%
via Nontrade Good	5%, 2%, 13%	8%, 6%, 26%
Consumption Elasticity of Subsitution		
Unitary	σ = 1	
"Intermediate"	σ = ¾	
"Low"	σ = ½	
Remaining Parameters		
Leisure Share of Time in Large Economy		
(determines $\eta_{leisure}$)	40%	
Required Return on Capital (r_k)	10%	

Table 4: Summary of Numerical Results

	Productivity-Driven Crowding						Quality-of-Life-Driven Crowding					
	Base Specification			Alternate Specification			Base Specification			Alternate Specification		
	σ = 1	σ = ¾	σ = ½	σ = 1	σ = ¾	σ = ½	σ = 1	σ = ¾	σ = ½	σ = 1	σ = ¾	σ = ½
At Relative Pop. Density = 8												
$A_{X,s}/A_{X,l}$ or $(e(q_s)-e(q_l))$	1.44	1.47	1.51	1.66	1.74	1.85	0.21	0.21	0.22	0.21	0.22	0.23
w_s/w_l	1.23	1.27	1.31	1.58	1.68	1.82	0.76	0.75	0.75	0.79	0.79	0.78
$r_{D,s}/r_{D,l}$	10.0	10.5	11.2	12.7	13.9	15.5	5.95	6.22	6.51	6.30	6.57	6.85
$p_{Z,s}/p_{Z,l}$	2.04	2.10	2.18	2.24	2.37	2.55	1.31	1.32	1.32	1.24	1.25	1.25
x_s/x_l	1.18	1.15	1.11	1.44	1.36	1.27	0.82	0.82	0.83	0.84	0.84	0.84
z_s/z_l	0.58	0.66	0.75	0.64	0.71	0.80	0.63	0.67	0.72	0.68	0.71	0.75
$leisure_s/leisure_l$	0.95	0.96	0.97	0.91	0.93	0.94	1.08	1.02	0.96	1.06	1.01	0.95
$(D_{Z,s}/Z_s)/(D_{Z,l}/Z_l)$	0.20	0.20	0.19	0.18	0.17	0.16	0.18	0.16	0.14	0.17	0.15	0.14
At Relative Pop. Density = 32												
$A_{X,s}/A_{X,l}$ or $(e(q_l)-e(q_s))$	1.83	1.93	2.08	2.24	2.50	2.93	0.32	0.33	0.35	0.33	0.35	0.37
w_s/w_l	1.41	1.50	1.64	2.03	2.34	2.90	0.63	0.63	0.62	0.68	0.67	0.66
$r_{D,s}/r_{D,l}$	45.9	51.2	59.3	65.5	79.2	103.0	19.5	21.1	22.8	21.5	23.1	24.7
$p_{Z,s}/p_{Z,l}$	3.25	3.48	3.83	3.66	4.17	5.04	1.56	1.58	1.60	1.43	1.44	1.46
x_s/x_l	1.31	1.27	1.22	1.78	1.69	1.56	0.72	0.73	0.73	0.76	0.75	0.74
z_s/z_l	0.40	0.50	0.62	0.49	0.58	0.69	0.46	0.52	0.58	0.53	0.57	0.62
$leisure_s/leisure_l$	0.93	0.94	0.95	0.88	0.89	0.92	1.14	1.04	0.93	1.12	1.02	0.91
$(D_{Z,s}/Z_s)/(D_{Z,l}/Z_l)$	0.07	0.07	0.06	0.06	0.05	0.05	0.05	0.05	0.04	0.05	0.04	0.04
Elasticity with Pop. Density												
w_s	0.10	0.11	0.13	0.21	0.25	0.29	-0.13	-0.14	-0.14	-0.11	-0.12	-0.12
$r_{D,s}$	1.11	1.13	1.17	1.21	1.26	1.32	0.86	0.88	0.90	0.88	0.91	0.93
$p_{Z,s}$	0.34	0.36	0.38	0.38	0.41	0.46	0.13	0.13	0.14	0.10	0.11	0.11
x_s	0.08	0.07	0.05	0.17	0.15	0.12	-0.09	-0.09	-0.09	-0.08	-0.08	-0.09
z_s	-0.26	-0.20	-0.14	-0.21	-0.16	-0.11	-0.22	-0.19	-0.16	-0.19	-0.16	-0.14
$leisure_s$	-0.02	-0.02	-0.01	-0.04	-0.03	-0.03	0.04	0.01	-0.02	0.03	0.00	-0.03
$D_{Z,s}/Z_s$	-0.77	-0.78	-0.79	-0.83	-0.85	-0.87	-0.84	-0.89	-0.94	-0.87	-0.90	-0.93

Note: elasticity is measured at a relative population density of 4, which is the ratio of the population-weighted mean density for urbanized areas with population greater than 100,000 to the least dense of such urbanized areas.

Figure 1: Productivity-Driven Crowding



Parameters:

Traded-Good Factor Shares: $\alpha_{X,D} = 0.10$, $\alpha_{X,K} = 0.25$

Nontraded-Good Factor Shares: $\alpha_{Z,D} = 0.25$, $\alpha_{Z,K} = 0.10$

Large-Economy Nontraded-Good Consumption Share: $\frac{p_l z_l}{x_l + p_l z_l} = 0.20$

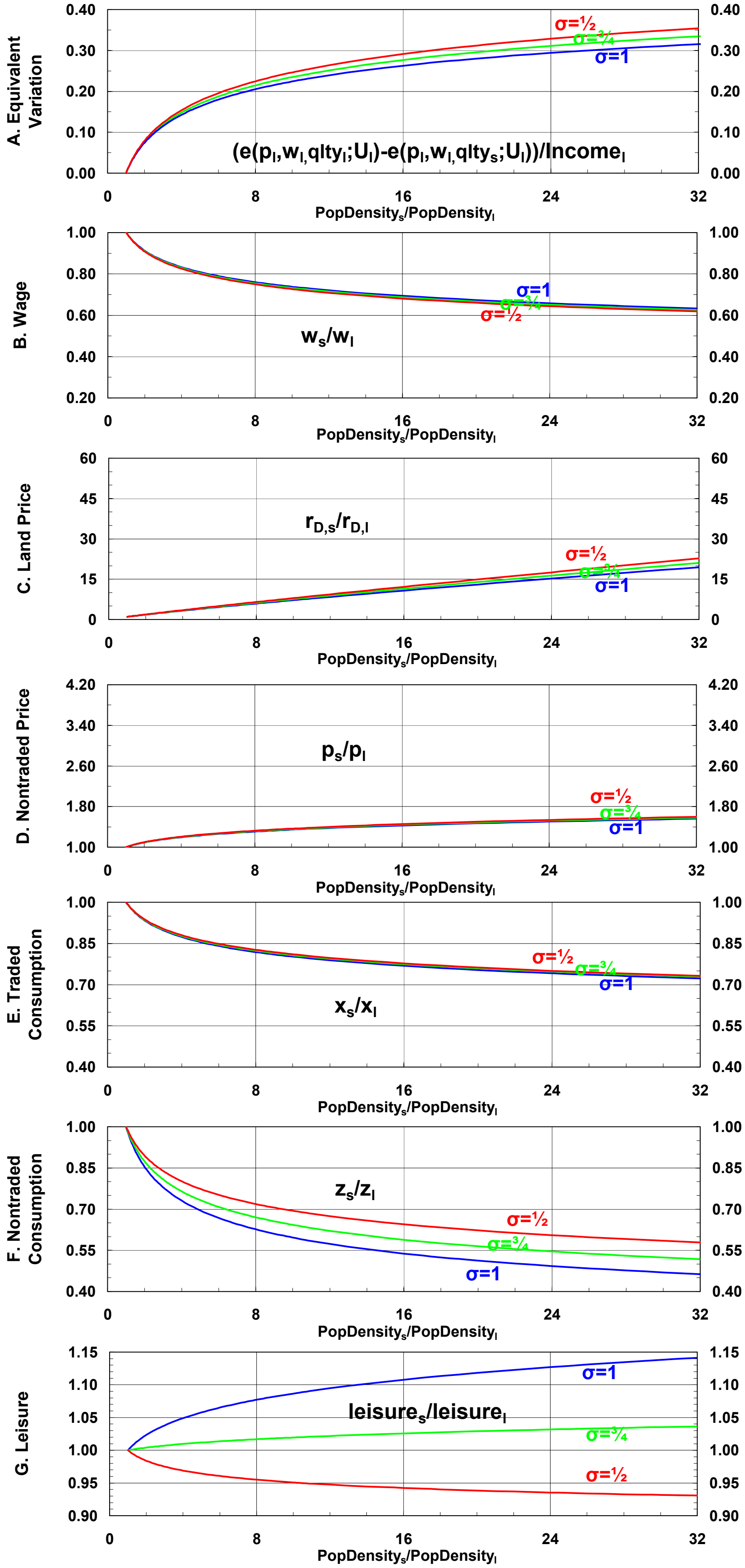
Large-Economy Leisure: $leisure_l = 0.40$

Small-Economy Relative Land Area: $\frac{D_s}{D_l + D_s} \approx 0$

Required Capital Rent: $rent_K = 0.10$

Elasticity of Substitution: σ = 1, σ = ¾, σ = ½

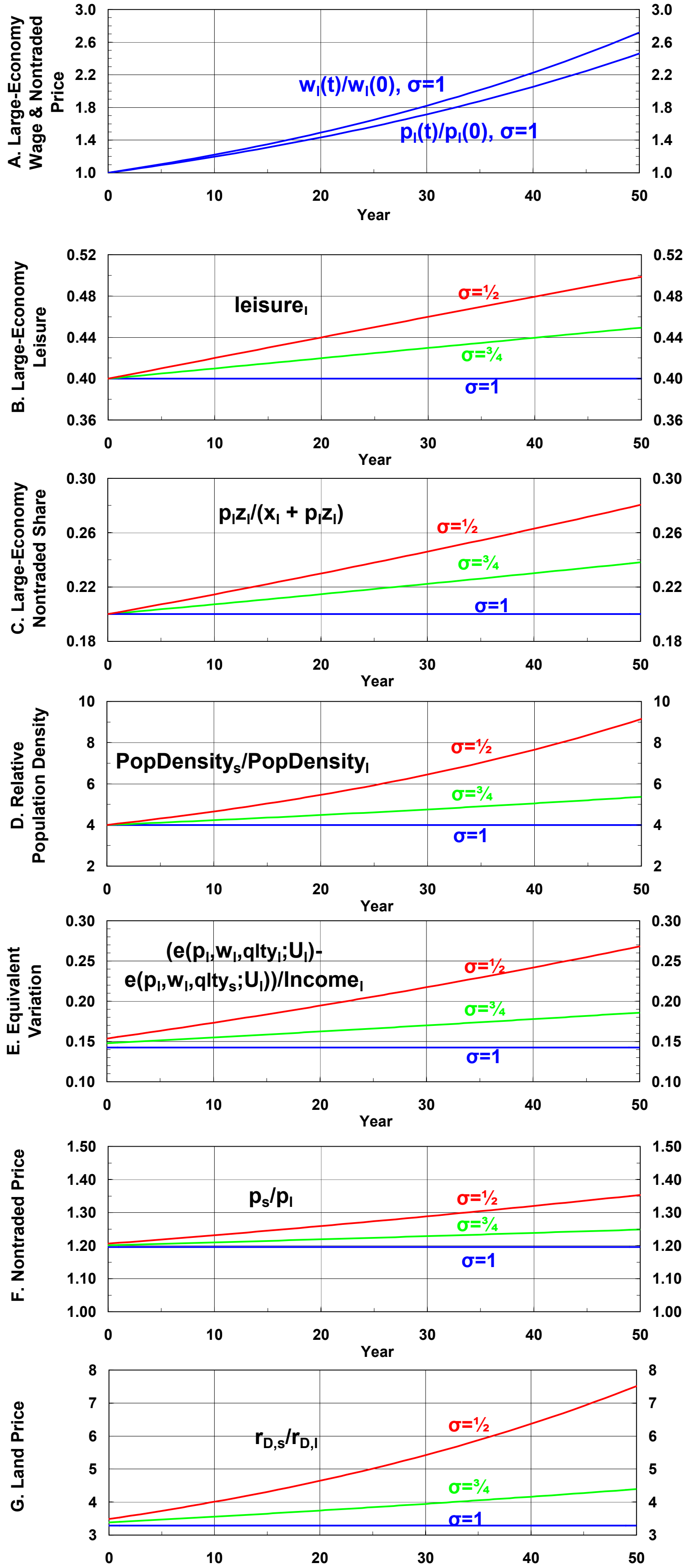
Figure 2: Quality-of-Life-Driven Crowding



Parameters:

Traded-Good Factor Shares	$\alpha_{X,D} = 0.10$ $\alpha_{X,K} = 0.25$
Nontraded-Good Factor Shares	$\alpha_{Z,D} = 0.25$ $\alpha_{Z,K} = 0.10$
Large-Economy Nontraded-Good Consumption Share	$\frac{p_l z_l}{x_l + p_l z_l} = 0.20$
Large-Economy Leisure	$leisure_l = 0.40$
Small-Economy Relative Land Area	$\frac{D_s}{D_l + D_s} \approx 0$
Required Capital Rent	$rent_K = 0.10$
Elasticity of Substitution	$\sigma = 1$ $\sigma = ¾$ $\sigma = ½$

Figure 3: TFP Growth and Crowding



Parameters:

Traded-Good Factor Shares: $\alpha_{X,D} = 0.10$, $\alpha_{X,K} = 0.25$

Nontraded-Good Factor Shares: $\alpha_{Z,D} = 0.25$, $\alpha_{Z,K} = 0.10$

Large-Economy Nontraded-Good Consumption Share at t=0: $\frac{p_l(0)z_l(0)}{x_l(0)+p_l(0)z_l(0)} = 0.20$

Large-Economy Leisure at t=0: $leisure_l(0) = 0.40$

Small-Economy Relative Land Area: $\frac{D_s}{D_l + D_s} \approx 0$

Traded-Good TFP Growth: $\gamma_X = 0.015$

Nontraded-Good TFP Growth: $\gamma_Z = 0$

Elasticity of Substitution: σ = 1, σ = ¾, σ = ½