WHY ARE POPULATION FLOWS SO PERSISTENT?

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Abstract

A neoclassical model of local growth is developed by integrating the static equilibrium underlying compensating differential theory as the steady state of a neoclassical growth model. Numerical results show that even very small frictions to labor and capital mobility along with small changes in local productivity or local quality of life suffice to cause highly persistent population flows. Wages and house prices, in contrast, jump most of the way to their new steady state. The model suggests that cross-sectional regressions of local population growth can help to identify past and present changes in the determinants of representative-agent welfare. More generally, it provides a framework for interpreting observed local growth rates.

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1 Introduction

Persistent population flows strongly characterize local U.S. growth during the twentieth century. Local areas that grow rapidly during one decade tend to do so over the next few decades as well. Across U.S. states, high persistence has been documented for employment growth over the periods 1909 to 1953 and 1950 to 1990, and for net migration over the period 1900 to 1987 (Borts [7], Blanchard and Katz [5], Barro and Sala-i-Martin [3]). Across U.S. cities, high persistence has been documented for population growth over the period 1950 to 2000 (Glaeser, Scheinkman, and Shleifer [15]; Glaeser and Gyourko [14], Rappaport [25]). And across U.S. counties, population growth becomes highly persistent starting around 1930 (Table 1 Panel A). Why are population flows so persistent?

One possible explanation is a continuous rise in the steady-state population of some localities relative to others. But if this were the case, income growth and house price growth would be persistent as well. Instead, they show positive serial correlation between some adjacent decades but negative serial correlation between others (Table 1 Panels B and C). How can we reconcile the persistent population flows with the varied pattern of income and house price growth?

Another possible explanation for the persistent flows is that they primarily derive from the slow decline of durable housing stock. If this were the case, persistence would be much higher for localities that are losing population than it is for those that are gaining population. Glaeser and Gyourko [14] indeed find higher persistence for declining U.S. cities compared to growing ones. But for U.S. counties, persistence is at least as high for those that are growing as it is for those that are declining.

Understanding the persistence of population flows requires an explicitly dynamic model of local economic growth. This paper develops exactly such a model by integrating the static equilibrium underlying compensating differential theory (Rosen [30], Roback [29]) as the long-run steady state of a neoclassical growth model. Doing so builds on the idea expressed by Mueser and Graves [22] that population and firm locational movements should be proportional to utility and profit differentials. More formally, Braun [8] introduces labor mobility into the neoclassical growth framework by assuming that labor flows are proportional to the difference in the net present value of labor income. The present model builds on the Braun model by endogenizing local house prices, which both dampen population flows and serve as the source of long-run congestion.

A neoclassical local growth model complements the extensive new economic geography literature (e.g, Krugman [20]; Fujita, Krugman, Venables [11]; Fujita and Thisse [12]). That literature is primarily concerned with the spatial distribution of economic activity that follows from an increasing-returns component of local productivity. The neoclassical local growth model takes local productivity as given and instead focuses on the transition from one steady state to another.

Numerical solutions to the neoclassical local growth model show that even very small frictions to labor and capital mobility along with small changes in either underlying local productivity or local quality of life suffice to cause highly persistent population flows. Wages and house prices, in contrast, jump most of the way to their new steady states. Wages can also both rise and fall as they transition to their new steady state. Such jumps and nonmonotonic dynamics can account for the low observed persistence of per capita income growth and house price growth.

The neoclassical local growth model has several important empirical implications. First is that steady-state local population density serves as an excellent measure of the contributions from local characteristics to representative-agent welfare. Second, the distribution of U.S. population across localities has significantly differed from its steady state during much of the twentieth century. But contrary to Greenwood et al. [17], this difference does not imply that local wages and house prices are far from their steady state. Third, cross-sectional regressions of population growth on local characteristics can help to identify past and present changes in the contributions from such characteristics to representative-agent welfare. More generally, the neoclassical local growth model helps us to interpret observed local growth rates. It identifies types of possible shocks from which an observed pattern of local growth can arise.

The paper proceeds as follows. Section 2 lays out the model. Section 3 describes the numerically-derived impulse response functions from one-time changes to local productivity and local quality of life, and from a one-time shock to local capital stock. Section 4 discusses some alternative sources of persistent population flows. Section 5 discusses the empirical implications of the model. A last section briefly concludes.

2 A Neoclassical Model of Local Growth

The local growth model developed herein is a slight variation on the standard Ramsey-Cass-Koopmans neoclassical growth framework (Ramsey [23], Cass [9], Koopmans [19]). The world is assumed to be composed of two open economies, one small and one large. The small economy is interpreted as a "locality", a well-defined market for both labor and nontraded goods with high factor mobility between it and the large economy. The large economy is interpreted as an integrated macroeconomy composed of numerous other localities. The size distinction implies that nothing that occurs in the small economy affects what goes on in the large economy.

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 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 individuals' utility functions; examples might include moderate climates, scenic vistas, and natural recreational endowments.

In a steady state, the small economy must offer individuals and firms identical levels of utility and profits to what is available in the large economy. This is exactly the assumption underlying the compensating differential literature. But in the present dynamic context, frictions to labor and capital mobility cause extended equilibrium transition paths during which utility and profits may differ between the two economies.

A final change to the standard neoclassical growth setup is that individual utility is augmented to include consumption of a nontraded good. Herein, I simply assume a constant flow supply of the nontraded good. A natural interpretation is that it corresponds to housing services. This constant flow supply serves as the *only* source of long-term congestion.

Various elements of this neoclassical local growth model already exist within the economics literature. Topel [33] constructs a partial-equilibrium dynamic model of the forwardlooking migration and wage response to temporary and permanent changes in labor demand. Mueser and Graves [22] suggest a general-equilibrium dynamic model in which population and firm locational movements are proportional to utility and profit differentials. And Braun [8] formally introduces labor mobility into a neoclassical growth model by assuming that labor flows are proportional to the difference in the net present value of wages.

Though straightforward, the current model is a challenge to present due to the large number of associated variables and equations. Herein I highlight just the setup and the results; all derivations are available upon request. The remainder of this section is divided into six subsections: firm behavior, individual behavior, the large-economy steady state, individuals' decision to migrate, the small-economy dynamic system, and the small-economy steady state.

2.1 Firms

Within each economy ($i = l, s$) are a number of firms employing a constant-returns-to-scale (CRS) production function that combines capital, K_i, and labor, L_i, to produce a traded numeraire good, Y_i. As CRS implies an indeterminate firm size, I write instead the aggregate production and capital evolution functions,

$$Y_i(t) = A_i(t) K_i(t)^{\alpha} L_i(t)^{1-\alpha} \tag{1}$$

$$\dot{K}_i(t) = I_i(t) - \delta K_i(t) \tag{2}$$

A_i measures economy-specific total factor productivity, one of the key exogenous parameters potentially distinguishing the small from the large economy. Remaining exogenous parameters, assumed to be identical across the two economies, are the share of income accruing to the owners of capital, α, and the rate of capital depreciation, δ. I_i denotes endogenously-determined gross investment.

Firms choose their level of employment and gross investment to maximize the net present value of cash flows,

$$V_i(t) = \int_t^{\infty} \left(Y_i(v) - w_i(v) L_i(v) - I_i(v) - \frac{b_{K,i}}{2} \frac{I_i(v)}{K_i(v)} I_i(v) \right) \mathrm{e}^{-r(v-t)} \mathrm{d}v \tag{3}$$

Along the lines of Abel [1] and Hayashi [18], (3) posits an average adjustment cost to each unit of gross investment that increases linearly in the rate of gross investment with constant of proportionality $\frac{b_{K,i}}{2}$. Such a specification is often labeled "quadratic" as total adjustment costs are indeed so. The real interest rate, r, is assumed to remain at its large-economy steady state. Setting up and solving the Hamiltonian associated with firms' maximization gives standard results. In particular, the first-order condition with respect to $I_i(t)$ implies that firms' rate of gross investment can be written as a linearly increasing function of the shadow value of capital, $q_i(t)$, (i.e., the capital co-state variable).

$$\frac{I_i(t)}{K_i(t)} = \frac{q_i(t) - 1}{b_{K,i}} \tag{4}$$

Let lowercase variables denote per capita levels (e.g., $k_i(t) \equiv \frac{K_i(t)}{L_i(t)}$). Then (4) can be substituted into the capital accumulation equation, (2), to give

$$\frac{\dot{k}_i(t)}{k_i(t)} = \left(\frac{q_i(t) - 1}{b_{K,i}} - \delta - \frac{\dot{L}_i(t)}{L_i(t)} \right) \tag{5}$$

Similarly substituting into the first-order condition with respect to the shadow value of capital gives

$$\dot{q}_i(t) = (r + \delta) q_i(t) - \alpha A k_i(t)^{-(1-\alpha)} - \frac{(q_i(t) - 1)^2}{2b_{K,i}} \tag{6}$$

2.2 Individuals

Individuals within each of the two economies ($i = l, s$) are indexed by j to denote their asset wealth. They derive utility from consumption of a traded numeraire good, $c_{i,j}(t)$; from consumption of nontraded housing services, $d_{i,j}(t)$; and from the exogenously-specified quality of life associated with living in each of the two economies, $quality_i$.

$$U_{i,j}(t) = \int_t^\infty \left((1 - \zeta) \log(c_{i,j}(v)) + \zeta \log(d_{i,j}(v)) + \log(quality_i) \right) \mathrm{e}^{-\rho(v-t)} \, \mathrm{d}v \tag{7}$$

Asset accumulation is the sum of individuals' nonwage and wage income less their expenditure on traded-good and housing-service consumption. Letting p_i be the numeraire price of housing services,

$$\dot{assets}_{i,j}(t) = r \cdot assets_{i,j}(t) + w_i(t) - c_i(t) - p_i(t) d_{i,j}(t) \tag{8}$$

Additionally, individuals face a lifetime budget constraint that the net present value of their consumption not exceed the sum of their asset wealth and labor wealth. Let labor wealth be given by $h_i(t) \equiv \int_t^\infty w_i(v)\, \mathrm{e}^{-r(v-t)} \mathrm{d}v$. Note that within each economy, labor wealth is identical for all individuals. Let total wealth be given by $wealth_{i,j}(t) \equiv assets_{i,j}(t) + h_i(t)$. Then,

$$\int_t^\infty (c_{i,j}(v) + p_i(t)\, d_{i,j}(v))\, e^{-r(v-t)}\, \mathrm{d}v \le wealth_{i,j}(t) \tag{9}$$

The solution to individuals' optimization gives that individuals spend the fraction ρ of their total wealth on current consumption. Of this, they spend the fraction $(1-\zeta)$ on the traded good and the remaining fraction ζ on housing services. The actual quantity of housing services consumed depends on the housing rental price.

$$c_{i,j}(t) = \rho(1-\zeta)\, wealth_{i,j}(t) \tag{10}$$

$$d_{i,j}(t) = \frac{\rho\zeta}{p_i(t)} wealth_{i,j}(t) \tag{11}$$

The homotheticity of individuals' utility function implies that aggregate demand for each good is a function of aggregate wealth. Hence each of (10) and (11) can be rewritten in terms of average traded-good and average housing-service consumption, $\overline{c}_i(t)$ and $\overline{d}_i(t)$, as a function of average wealth, $\overline{wealth}_i(t)$.

Local housing services are assumed to flow at a constant aggregate rate, D_i. And population within each of the economies is assumed to be instantaneously fixed at $L_i(t)$. So average housing consumption, $\overline{d}_i(t)$, must equal $D_i/L_i(t)$. The current rental price of housing services, $p_i(t)$, is just the price that realizes this level of housing demand. It follows immediately from (11) that

$$p_i(t) = \frac{1}{D_i} \rho\zeta\, \overline{wealth}_i(t)\, L_i(t) \tag{12}$$

The sales price of housing services can then be calculated as the net present value of the housing rental price,

$$value_i(t) \equiv \int_t^\infty p_i(v)\ \mathrm{e}^{-r(v-t)} \mathrm{d}v$$

The traded-good and housing consumption functions, (10) and (11), allow for an easy decomposition of individuals' lifetime utility into elements that depend separably on individuals' total wealth, the time path of local housing rental prices, local quality of life, and a function that depends on only exogenous parameters.

$$U_{i,j}(t) = \frac{1}{\rho}\log\left(wealth_{i,j}(t)\right) - \zeta\int_t^{\infty}\log\left(p_i(v)\right)\mathrm{e}^{-\rho(v-t)}\mathrm{d}v + \frac{1}{\rho}\log\left(quality_i\right) + \mathrm{f}(\rho,\zeta,r) \tag{13a}$$

$$= U_{i,j}^{\text{wealth}}(t) + U_i^{\text{price}}(t) + U_i^{\text{quality}} + \mathrm{f}(\rho,\zeta,r) \tag{13b}$$

2.3 Large-Economy Steady State

In contrast to the small economy, the large economy is assumed to remain at its steady state. In particular, the size distinction allows for constant large-economy population notwithstanding net migration between it and the small economy (i.e., $\dot{L}_l(t)/L_l(t) = 0$).

The large economy's steady state is characterized by standard neoclassical results. Constant individual consumption implies an interest rate equal to individuals' rate of time preference, $r = \rho$. Capital intensity and the shadow value of capital can be derived using (5) and (6). Letting $\widetilde{b}_{K,i} \equiv 2(\delta+\rho) + b_{K,i}(\delta^2 + 2\delta\rho)$ gives

$$q_l = 1 + \delta b_{K,l} \tag{14}$$

$$k_l = A_l^{\frac{1}{1-\alpha}}\left(\frac{2\,\alpha}{\widetilde{b}_{K,l}}\right)^{\frac{1}{1-\alpha}} \tag{15}$$

Net borrowing among individuals in the large economy is zero. So average large-economy asset wealth must exactly equal the per capita value of large-economy installed capital plus housing stock. Combining this adding up constraint with (12) and the steady-state interest rate, $r = \rho$, determines the rental price of housing services.

$$\overline{assets}_l = q_l\,k_l + value_l\,\overline{d}_l \tag{16}$$

$$p_l = \frac{\rho\zeta}{\overline{d}_l(1-\zeta)}\left(q_l\,k_l + h_l\right) \tag{17}$$

2.4 Labor Mobility

Individuals choose where to live by comparing their utility from residing forever within the small economy versus their utility from residing forever within the large economy. Let $\triangle U_j(t)$

be the resulting utility difference for an individual with asset wealth j, $U_{s,j}(t) - U_{l,j}(t)$. It follows that there will be an incentive for migration from l to s whenever $\triangle U_j(t)$ is positive and an incentive for migration from s to l whenever $\triangle U_j(t)$ is negative.

The utility difference from living in the small relative to the large economy can be decomposed analogously to (13b): $\triangle U_j(t) = \triangle U_j^{\text{wealth}}(t) + \triangle U^{\text{price}}(t) + \triangle U^{\text{quality}}$. Using (13a) and the definition of total wealth, these components can be written as

$$\triangle U_j^{\text{wealth}}(t) = \frac{1}{\rho}\log\left(\frac{h_s(t) + assets_{s,j}(t)}{h_l + assets_{s,j}(t)}\right) \tag{18a}$$

$$\triangle U^{\text{price}}(t) = \zeta\int_t^{\infty}\log\left(\frac{p_l}{p_s(v)}\right)\mathrm{e}^{-\rho(v-t)}\mathrm{d}s \tag{18b}$$

$$\triangle U^{\text{quality}} = \frac{1}{\rho}\log\left(\frac{quality_s}{quality_l}\right) \tag{18c}$$

The quotient in (18a) captures a potential migrant's wealth in the small economy relative to what it would be in the large economy. Moving implies a change in labor wealth but not in asset wealth.

An immediate question arises: what is the asset wealth of potential migrants? The wealth component of the utility differential, (18a), implies that the lower an individual's asset wealth, the greater their utility gain or loss for a given difference in labor wealth. The dependence of utility differentials on potential migrants' asset wealth echoes the result that in a lifecycle framework, younger workers have a larger incentive to migrate in response to local wage differentials (Topel [33]).

For simplicity, I assume that individuals migrating from the large to the small economy have asset wealth equivalent to the small economy's contemporary mean, $\overline{assets}_s(t)$. Consistent with Tiebout's [32] hypothesis that migration sorts a heterogenous population into more homogenous sub-populations, the assumption implies that migration sorts residents based on their asset wealth. I additionally assume that prior to any shocks, all small-economy residents have large-economy mean asset wealth. It follows that small-economy asset wealth will always remain homogeneous. The main numerical result that follows — the high persistence of population flows following small changes to local productivity and local quality of life — does *not* depend on these assumptions.

A more important assumption is that small-economy residents' asset wealth does not depend on small-economy asset prices. Instead, small-economy residents fully diversify their asset holdings across the integrated macroeconomy. So for the small economy, (16) need not hold.

The Tiebout wealth sorting and diversified asset holding assumptions along with the consumption first-order conditions imply that small-economy asset wealth evolves according to

$$\dot{assets}_s\left(t\right) = w_s\left(t\right) - \left(r - \rho\right) assets_s\left(t\right) - \rho\, h_s\left(t\right) \tag{19}$$

Since the interest rate remains at its steady state, the middle term on the right-hand side drops out.

Analogous to the installation cost associated with capital investment, I assume a labor mobility friction in the form of a utility cost that is linearly increasing in the rate of net migration with constant of proportionality b_L.

$$U^{\text{cost}} = b_L \left| \frac{\dot{L}_s\left(t\right)}{L_s\left(t\right)} \right| \tag{20}$$

Modeling the labor friction as a utility cost rather than a wealth cost is done for analytical tractability. A wealth cost proportional to net flows implies nearly identical dynamics.

To motivate the labor mobility friction, consider rental prices for one-way, do-it-yourself moving trucks. Suppose there were a net flow of individuals from East to West. Demand for rental trucks would be high in the East while their supply would be high in the West. The higher the net flow west, the higher westbound relative prices would need to be to equilibrate supply and demand. It is hard to imagine such moving prices being large, and so the calibrations below will show results for net migration frictions that are "very small". Sources of larger frictions proportional to net migration might include the adjustment of local infrastructure, housing stock, and public services. Of course, numerous other labor mobility frictions may arise that are not proportional to net flows.

In an equilibrium, the flow between s and l must be such that individuals with small-economy asset wealth are indifferent between migrating or not. This will be the case when the utility cost associated with migrating exactly equals the incremental lifetime utility associated with living in the destination location. Equilibrium net migration into the small economy is given by

$$\frac{\dot{L}_s(t)}{L_s(t)} = \frac{\triangle U_j(t)}{b_L} \tag{21}$$

The assumed Tiebout wealth sorting implies that $\triangle U_j(t)$ is evaluated for individuals with asset wealth equal to $\overline{assets}_s(t)$.

2.5 Dynamic System

A dynamic system characterizing the small economy's equilibrium transition to its steady state can now be expressed as a system of seven differential equations in $\{L_s(t),\ k_s(t),\ assets_s(t),\ q_s(t),\ \triangle U^{\text{wealth}}(t),\ \triangle U^{\text{price}}(t),\ value_s(t)\}$. The first three of these, $\{L_s(t),\ k_s(t)$, and $assets_s(t)\}$, are "state" variables, which are instantaneously fixed (i.e., they can not jump). The remaining four, $\{q_s(t),\ \triangle U^{\text{wealth}}(t),\ \triangle U^{\text{price}}(t)$, and $value_s(t)\}$, can jump but only in reaction to unexpected system shocks. The actual expressions for the differential equations included in the paper's supplemental materials (Rappaport [27]).

Any remaining endogenous variables can be calculated from the contemporary values of these seven system variables along with the various exogenous parameters.

2.6 Small-Economy Steady State

The small-economy steady state is derived by setting each of the seven system differential equations equal to zero. The actual expressions are included in the paper's supplemental materials. Two of the steady-state values, $k_s^*(t)$ and $q_s^*(t)$, are determinate in the sense that they can be expressed as a function of exogenous parameters alone. The remaining five steady-state values, $\{L_s^*(t),\ assets_s^*(t),\ \triangle U^{\text{wealth},*}(t),\ \triangle U^{\text{price},*}(t)$, and $value_s^*(t)\}$, collectively have one degree of freedom in the sense that one of them needs to be known to determine the other four.

The "extra" degree of freedom captures that the small-economy system is subject to history dependence. In particular, consumption smoothing (along with an implicit incomplete market for insurance) implies that steady-state asset wealth depends on the history of local shocks. Steady-state asset wealth, in turn, affects both steady-state house prices and population. The history dependence of the small-economy steady state is crisply illustrated below by the transition dynamics following a negative capital shock.

Comparative steady-state "statics" can now be calculated for various local observables. Table 2 contains a summary. In contrast to Roback [29], higher small-economy quality of life has no effect on small-economy wages. The difference is due to the exclusion of land from the traded-good production function. With land included as a factor of traded-good production, the derivative of local population with respect to local productivity can be either positive or negative. As land's factor income share of traded-good production goes to one, increased productivity can crowd out population. Intuitively, land may be too valuable to allow much of it to be used for housing. But Rappaport [28] shows such crowding out to occur only when labor's factor income share is unrealistically close to zero.

3 Transition Dynamics

Numerical solutions readily sketch out the small economy's transition to its new steady state following small one-time changes to its productivity and to its quality of life. Small frictions to labor and capital mobility interact to cause highly persistent population flows. In contrast, wages and house prices can immediately jump to close much of the distance to their new steady states.

A preliminary subsection discusses the calibration of the model. A last subsection describes transitions following a one-time shock to the small economy's capital stock.

3.1 Calibration

To give meaning to the idea that the capital and labor frictions are "small", the associated parameters $b_{K,i}$ and b_L are mapped to more intuitive measures. The capital friction will henceforth be assumed to be equal across the two economies. For given rates of depreciation and exogenous technological progress, it maps one-to-one via (14) to the steady-state shadow value of capital, q_K^*. Similarly, for a given rate of time preference, the labor friction maps one-to-one via (18a) and (21) to the constant of proportionality measuring a linear response to a log difference in real wealth, which will be denoted μ. In other words, $\dot{L}_s/L_s = \mu \log(wealth_s/wealth_l)$.

Aggregate empirical time series suggest that the shadow value of capital remains close to one (Summers [31]; Blanchard, Rhee, and Summers, [6]). However, more recent research using panel data on firms suggests that the steady-state shadow value of capital lies in the range 1.2 to 1.8 (Barnett and Sakellaris [2]). Herein, $q_K^* = 1.48$ is chosen as a base calibration, but all results are robust to substantially higher or lower capital mobility.

Empirical estimates leave wide latitude in parameterizing labor mobility. Looking at the relationship between net migration and initial wage levels for U.S. states, Barro and Sala-i-Martin [3] find that the net migration response to current income differences is below $\mu = \frac{1}{25}$. Regressing net migration on a constructed measure of expected income differences, Greenwood et al. [17] find a response equivalent to $\mu = \frac{1}{5}$. Using a different methodology to control for future income differences, Gallin [13] finds that U.S. labor mobility may approximate $\mu = 2$.[1] All of these estimates are likely to be strongly biased downward since they assume that no part of observed wage differences compensates for varying local quality of life. Nor do the Barro and Gallin estimates control for varying local house prices. The transition paths below assume a base level of labor mobility of $\mu = 2$. As discussed below, all qualitative results are robust to substantially higher and lower labor mobility.

The share of income accruing to the owners of capital is assumed to be one third, $\alpha = \frac{1}{3}$. Such a calibration corresponds to a literal interpretation of physical capital and approximately matches the share of national income accounted for by rental income, profits, and interest payments. Difficulty calibrating neoclassical growth models to match empirical observations has led authors such as Mankiw, Romer, Weil [21] and Barro and Sala-i-Martin [4] to argue for a more metaphorical interpretation of capital, for instance to include human capital. All qualitative results are robust to a broader calibration of the capital factor income share.

Remaining parameters are set to standard values. The depreciation rate and rate of time preference are respectively set to 6% and 3%, $\delta = 0.06$ and $\rho = 0.03$. The housing consumption share is set to 15%, $\zeta = 0.15$, which approximately matches the share of U.S.

[1] Gallin estimates that a 1% wage difference that lasts for one year induces a net migration rate of 0.09%. Assuming a 3% real interest rate and a thirty-year time horizon, a one-period 1% wage difference implies a 0.049% labor wealth difference. So Gallin's result implies that such a 0.049% labor wealth difference suffices to induce a 0.09% migration rate, in turn implying $\mu = 1.85$.

personal consumption expenditures imputed to housing services. All qualitative results are robust to a broader interpretation of nontraded goods to include, e.g., local distribution services.

3.2 Change in Small-Economy Productivity

Figure 1 shows the impulse response following a one-time permanent increase in small-economy productivity that causes steady-state wages to increase by 5%. For an economy with a one-third capital factor income share, such a change is equivalent to a 3.3% increase in total factor productivity. It follows that wages also jump by 3.3%, thereby immediately closing 66% of the gap to their new steady state (Panel B). The remaining rise in wages is achieved through capital deepening.

The initial jump in wages implies an initial jump in labor wealth, which in turn induces a population inflow (Panel A). Similarly, the increase in productivity and the future population inflow cause a jump in the shadow value of capital, thereby inducing a capital inflow (not shown). The jump in labor wealth also causes an identically-sized jump in the rental price of housing, which thereafter continues to rise due to the population inflow (Panel C). This rise in the time path of housing rental prices dampens the population inflow. The population inflow and the capital inflow reinforce each other in the sense that the population inflow slows the fall in the shadow value of capital and the capital inflow slows the rate at which individuals' utility returns to its steady-state level. The overall result is an extremely long transition. Immediately following the increase in productivity, population flows into the small economy at an annual rate of 1.1% (Panel D). Annual population growth remains above 0.4% through year 17, above 0.2% through year 32, and above 0.1% through year 49.

Wages respond nonmonotonically to the increase in productivity. Immediately following their jump, downward pressure from the population inflow slightly dominates upward pressure from the capital inflow. Thus, wages initially *decline* at a 0.04% annual rate. During the third year following the productivity increase, the capital inflow comes to dominate the labor inflow so that the annual rate of wage growth, $\gamma(w)$, turns slightly positive. But $\gamma(w)$ remains quite low, never exceeding a 0.04%. Even including the initial jump, $\gamma(w)$ averages just 0.3% over the first decade.

The initial jump in housing's rental price is accompanied by an even larger jump in its sales price, which immediately closes 63% of the gap to its new steady state (Panel C). Including the initial jump, the annual rate of house sales price growth, $\gamma(value)$, over the first decade averages 1.8%. But excluding the initial jump, $\gamma(value)$ is much lower. Immediately following the jump, it equals 0.4%. By year 14, it has fallen below 0.2%. By year 30, it has fallen below 0.1%.

To compare the modeled transition dynamics with observed growth rates, persistence can be quantified by the slowness with which growth returns to its long-run trend. Empirically, such autoregressive persistence is estimated by regressing growth on its lagged value: $g_{\tau,i} = \kappa + \rho g_{\tau-1,i} + \epsilon_{\tau,i}$. Henceforth ρ will denote autoregressive persistence rather than the rate of time preference. To correspond to the frequency of observed population, τ is assumed to measure decades. For the modeled transition dynamics, long-run trend growth is zero and so autoregressive persistence can be measured simply by dividing average annual growth during one decade by its value during the previous decade.

A critical caveat applies to comparing modeled persistence with estimated persistence. Under the null hypothesis that observed growth rates are generated by a stochastic version of the present model, the estimated persistence of growth will be biased toward zero relative to the persistence of growth's deterministic component. This bias becomes especially large as the deterministic component of growth goes to zero. Suppose that observed growth combines a "fundamental" component plus a normally-distributed noise component, $\gamma_t = \gamma_t^* + \epsilon_t$. The persistence of observed growth is given by $\rho = (\gamma_t^* + \epsilon_t)/(\gamma_{t-1}^* + \epsilon_{t-1})$. As the fundamental component becomes small, observed persistence will increasingly be determined by the noise component. In the limit as γ^* goes to zero, $\rho = \epsilon_t/\epsilon_{t-1}$, which has a Cauchy distribution with median zero and undefined variance. So while the persistence implied by the deterministic model may be $\rho^* = \gamma_t^*/\gamma_{t-1}^*$, estimated persistence is expected to be closer to zero. As γ_t^* becomes smaller, the bias becomes larger. The important implication is that when modeled growth becomes "small", it has very low predictive power for estimated persistence.[2]

[2] Of course, it's not clear what constitutes "small". Observed growth rates give a sense of magnitude. Mean annual growth rates for most county variables range from 0% to 3%. The corresponding standard deviations range from 1% to 3%. A description of the data underlying these and other observed growth rates is included in the paper's supplemental.

The persistence of modeled *population* growth is consistent with the estimated persistence of population growth, $\hat{\rho}_{\gamma(pop)}$. The latter is relatively low from the 1900s through the 1930s (Table 3 Panel A, columns 1 to 3). But it jumps to 0.47 between the 1930s and the 1940s and then to 0.75 between the 1940s and the 1950s (columns 4 and 5). Thereafter, $\hat{\rho}_{\gamma(pop)}$ varies from 0.45 to 0.67. Observed county net migration and employment growth yield similar persistence estimates. Modeled persistence lies toward the upper end of this estimated range. Under the base calibration, $\rho_{\gamma(pop)}$ between the first and second decades following the change in productivity equals 0.57. This rises to 0.63 between the second and third decades and eventually to 0.66 between the fourth and fifth decades.

The persistence of modeled *wage* growth is mostly consistent with its estimated persistence. As shown in the first four columns of Table 3 Panel B, point estimates of the persistence of median family income growth range from -0.29 to 0.17. Other observed proxies for wage growth give similar estimates. For modeled wage growth, persistence between an initial decade that includes the wage jump and the subsequent decade fall in this range. For example, between the first decade inclusive of the initial wage jump (i.e., from $t = 0^-$ to $t = 10$) and the subsequent decade, $\rho_{\gamma(w)}$ equals 0.12. With labor mobility substantially higher than under the base calibration, modeled persistence between these decades is moderately negative. Between decades that do not include the initial jump, modeled wage growth is extremely low. As discussed above, in such a case it is not appropriate to compare modeled with estimated persistence.

The persistence of modeled *house sales price* is possibly consistent with its estimated persistence. As shown in the last four columns of Table 3 Panel B, point estimates of $\hat{\rho}_{\gamma(value)}$ range from -0.35 to zero. Modeled persistence measured from an initial decade that includes the house price jump may be consistent with the upper end of this range. For example, $\rho_{\gamma(value)}$ between the first decade inclusive of the jump and the second decade equals 0.10. With higher labor and capital mobility, $\rho_{\gamma(value)}$ falls toward zero. But from an initial decade that excludes the house price jump, modeled persistence is much higher than estimated.

Population's long transition path, the high persistence of population growth, and the jumps by wages and house sales prices to close much of the gaps to their new steady states are very robust results.[3] A more detailed discussion and enumeration can be found in the paper's supplemental materials. What follows is a summary.

The most obviously important parameter determining the persistence of population flows is the degree of labor mobility. Figure 2 shows transition paths following an increase in small-economy productivity with "high" labor mobility, sixteen times that of the base calibration ($\mu = 32$) and with "low" labor mobility, one sixteenth that of the base calibration ($\mu = \frac{1}{8}$). Unsurprisingly, population *initially* flows into the small economy at a much quicker rate with high labor mobility (Panel A). Even so, population growth with high labor mobility remains relatively persistent. Between the first two decades, $\rho_{\gamma(L)}$ equals 0.35. And the annual rate of population growth remains above 0.2% through year 28 (Panel D). Regardless of labor mobility, the initial jump in wages equals the increase in productivity. But the more rapid inflow of population associated with high labor mobility subsequently puts greater downward pressure on wages, causing them to drift further below their steady state (Panel B). The faster population inflow also causes a much larger initial jump in the sales price of housing (Panel C).

The size of the capital installation friction also affects the persistence of population flows. Capital and population are complementary factors in production. Low labor mobility slows gross capital formation, and low capital mobility slows population growth. But even allowing for "high" capital mobility that is a multiplicative factor four times that of the base calibration (i.e., decreasing the capital installation friction such that the steady-state shadow value of capital falls from $q_K^* = 1.48$ to $q_K^* = 1.12$), population growth remains highly persistent with $\rho_{\gamma(L)}$ equal to 0.54 between the first and second decades and the annual rate of population growth remaining above 0.2% through year 29. Further reducing frictions by combining this high capital mobility with high labor mobility causes autoregressive persistence between the first two decades to drop to 0.28. But population growth still remains above 0.2% through year 21. So despite extremely high mobility, a modest small-economy productivity increase suffices to induce a relatively long transition.

As labor mobility and capital mobility together become infinite, initial population and

[3] Note, however, that nominal and real rigidities may cause larger and more prolonged deviations of wages and prices from their new steady-state levels.

wage growth similarly become infinite and all variables immediately jump to their new steady state. But as soon as a friction limits the inflow of *either* labor or capital, an extended transition results. Intuitively, if one of the two complementary factors flows in over time, the other "wants" to do so as well.[4]

3.3 Change in Small-Economy Quality of Life

Figure 3 shows the impulse response following a one-time permanent increase in the small economy's quality of life equivalent to 3.5% of large-economy consumption. In other words, $quality_s$ jumps to exceed $quality_l$ such that individuals in the large economy would be indifferent between increasing their consumption of both the numeraire and housing service goods by 3.5% while continuing to consume $quality_l$ versus maintaining their current level of consumption of the numeraire and housing goods but getting to consume $quality_s$.

The increase in small-economy quality of life induces a population inflow (Panel A). The population inflow induces a capital inflow (not shown). It also causes a sharp rise in the future time path of house rental prices, thereby dampening the incentive to migrate (Panel C). The population inflow, dampened by rising housing prices, and the capital inflow reinforce each other. The result is an extremely long transition. Immediately following the increase in quality of life, population flows into the small economy at an annual rate of 1.6% (Panel D. Population growth remains above 0.4% through year 18, above 0.2% through year 32, and above 0.1% through year 48.

Wages respond nonmonotonically to the increase in quality of life (Panel B). Immediately following the change, wages decline at a 0.3% annual rate. In year 12, they reach their nadir following a cumulative 1.2% decline. Subsequently, wage growth turns positive but remains quite small, never exceeding 0.03% per year. A caveat on wages' nonmonotonic response concerns the exclusion of land from the traded-good production function. In a generalized model that allows land to enter as a factor of production, an increase in quality of life causes a decrease in steady-state wages.[5] In such a generalized model, wages may either overshoot

[4] An appendix included in the paper's supplemental materials discusses the extended transition when labor is perfectly mobile but capital is not.

[5] For example, Rappaport [28] presents a static model of locational choice that includes land as a factor

their new steady state or else decline monotonically to it.

The rental and sales prices of housing services react in opposite directions to the increase in quality of life. Counterintuitively, rental prices jump very slightly downward concurrent with the change (Panel C). This downward jump reflects the lower labor wealth of current residents due to the lower future time path of their wages. In contrast, the future inflow of population causes *future* rental prices to rise sharply. As a result, housing sales prices immediately jump upward by 15.9%, thereby closing 62% of the gap to their new steady state. Including the initial jump, annual house price growth, $\gamma(value)$, over the first decade equals 1.8%. But exclusive of the initial jump, $\gamma(value)$ over the first decade averages just 0.3%. Thereafter, $\gamma(value)$ remains moderate. It falls below 0.2% during year 13 and below 0.1% during year 28.

The persistence of modeled growth rates following a change in quality of life can be compared against the empirical estimates shown in Table 3 and discussed in the subsection above. The persistence of modeled *population* growth lies within the range of empirical estimates. Between the first and second decades following the quality of life increase, $\rho_{\gamma(L)}$ equals 0.48. This rises to 0.58 between the second and third decades and eventually to 0.65 between the fourth and fifth decades.

The persistence of modeled *wage* growth is partly consistent with estimated persistence. For example, between the first and second decades following the change in quality of life, $\rho_{\gamma(w)}$ equals -0.14. However, the nonmonotonic path of wages implies that modeled persistence is extremely sensitive to when growth is measured. Along most of the transition path, persistence falls either well below or else well above the empirical estimates. But such large-magnitude persistences are underpinned by very low growth rates. As discussed above, the autoregressive persistence of modeled growth rates that are very low should not be compared with empirical estimates.

The persistence of modeled *house sales price* growth from an initial decade that includes the house price jump is possibly consistent with the upper end of estimates. Between the first and second decades inclusive of the jump, $\rho_{\gamma(value)}$ equals 0.10. With higher labor and

in the production of both traded and nontraded goods. Under its base calibration, an increase in quality of life that is comparable in size to that shown in Figure 3 causes steady-state wages to decline by 4.2%.

capital mobility, $\rho_{\gamma(value)}$ falls toward zero. But exclusive of the initial jump, the persistence of modeled house sales price growth substantially exceeds the empirical point estimates.

Population's long transition path, the high persistence of population growth, and the jump by house sales prices to close much of the gap to their new steady state are moderately robust results. Increasing labor mobility by a multiplicative factor of sixteen (to $\mu = 32$) causes $\rho_{\gamma(L)}$ between the first two decades to fall to 0.24 and house sales prices to jump to close 72% of the gap to their new steady state. Annual population growth remains above 0.2% through year 25. Additionally increasing capital mobility by a multiplicative factor of four (to $q_K^* = 1.12$) causes $\rho_{\gamma(L)}$ between the first two decades to fall to 0.20 and house sales prices to jump to close 81% of the gap to their new steady state. In this case, population growth remains above 0.2% through year 20. A more detailed discussion is included in the paper's supplemental materials.

3.4 Capital Shock

Figure 4 shows the impulse response following a shock to the small economy's capital stock that causes its wages to drop by 10%. Literally interpreted, such a negative capital shock might correspond to natural and man-made disasters. More metaphorically, it might correspond to changes in technology or the terms of trade that affect the small economy's installed capital base but that do not fundamentally alter its long-run productivity. A possible example is the effect of changes in steel manufacturing techniques on certain areas of the midwest United States during the early 1980s.

The negative capital shock causes wages and labor income to fall, thereby inducing a population outflow (Panel A). The fall in labor income is accompanied by an identically-sized fall in house rental prices, which then continue to fall due to the population outflow (Panel C). The lower rental prices dampen the incentive to exit the small economy. The capital shock also increases the marginal product and shadow value of capital thereby inducing a capital inflow (not shown). The population outflow and capital inflow cause wages to rise back towards their steady state (Panel B). As wages rise and housing rental prices fall, lifetime utility from residing in the small economy comes to equal and then surpass lifetime utility from residing in the large economy. Population stops exiting the small economy and starts returning.

The eventual population inflow, dampened by rising housing prices, and the capital inflow reinforce each other. The result is a long, slow transition by population, wages, and house prices to their steady state. Initial population growth of -1.8% per year becomes positive in year 11 following a cumulative 6.4% decline. Subsequently, $\gamma(pop)$ rises to just above 0.2% from years 19 through 26 and then remains above 0.1% through year 46. Following their 10% fall, wages initially grow at a 1.4% rate. Thereafter, $\gamma(w)$ remains above 0.4% through year 8, above 0.2% through year 13, and above 0.1% through year 19. Following a 4.6% discrete fall, the sales price of housing continues to decline at a very slight rate for 2 years. Thereafter, $\gamma(value)$ turns slightly positive, eventually increasing to just above 0.1% from years 8 through 24.

At the new steady state, small-economy population is above its original level. The equating of profits and utility requires wages and house prices to be the same between the two economies. But consumption smoothing during the transition causes small-economy residents to have lower asset wealth than before. The only way for the small economy's fixed supply of housing to be entirely consumed at the large-economy price is for small-economy population to rise. This crisply illustrates the history dependence discussed in the theory section above. The specific nature of the history dependence — that a negative capital shock causes an increase in steady-state population — is especially sensitive to assumptions. But the result that the small economy's steady-state population depends not just on current exogenous characteristics but also on the historical time series of local development is completely general.

Population's nonmonotonic response following a capital shock implies that its autoregressive persistence is extremely sensitive to when growth is measured. The reversal from negative to positive growth between the first two decades causes $\rho_{\gamma(L)}$ to equal -0.20. With "high" labor mobility, it equals -0.44. Such negative persistence of population growth contrasts with the empirical estimates motivating this paper. But as discussed below, there is evidence of strong negative persistence of population growth for U.S. counties that experienced population declines during the 1910s. Measured between decades starting just a few years after the capital shock, $\rho_{\gamma(L)}$ swings down to negative infinity and then back from positive infinity. But such extreme persistence is underpinned by very low initial-decade growth rates and so should not be compared to estimated persistence.

For wages and house sales prices, modeled persistence depends on whether the initial decade includes the negative jump. Between the first decade *inclusive* of the wage jump and the second decade, $\rho_{\gamma(w)}$ equals -0.57, which is moderately more negative than its estimated value for the 1970s through the 1990s (Table 3 Panel B, Columns 3 and 4). Between the first decade *exclusive* of the wage jump and the second decade, $\rho_{\gamma(w)}$ equals 0.25, which is close to its estimated value for the 1950s through the 1970s (Table 3 Panel B, Columns 1 and 2). Between the first two decades *inclusive* of the house price jump, $\rho_{\gamma(value)}$ equals -0.29, which is very close to its estimated value for the 1970s through the 1990s (Table 3 Panel B, Columns 7 and 8). And between the first two decades *exclusive* of the house price jump, initial house sales price growth is too small to make a comparison with estimated persistence meaningful.

The long transitions by population, wages, and house prices following a capital shock are extremely robust results. A more detailed discussion is included in the paper's supplemental materials and in Rappaport [24]. Of particular interest is that the speed at which wages return to their steady state is relatively insensitive to the degree of labor mobility. While higher labor mobility contributes to faster convergence due to the more rapid outflow of labor following the negative capital shock, this more rapid outflow drives down the marginal product of capital thereby slowing the gross capital inflow.

4 Alternative Sources of Persistence

The persistent population flows modeled herein derive from small frictions to labor and capital mobility causing extended transitions following discrete changes to steady-state local population. This section explores two alternative sources of population growth persistence. First is a gradual change in steady-state population. Second is the slow decline of durable housing.

Persistence arising from a gradual change in steady-state population is quite intuitive. Rather than the discrete changes in steady-state population that characterize the transitions above, local population remains continually at a steady state that itself is changing in a persistent matter. For example, Rappaport [26] argues that technological-progress-driven rising real incomes have caused individuals to continually increase their valuation of local quality of life in turn inducing a persistent migration to local areas with nice weather.

Persistent changes in steady-state population are surely an important source of persistent local population flows. Indeed, the literally instantaneous changes modeled herein are meant only as stylizations. But empirical evidence rejects that U.S. localities have remained at a persistently changing distribution of steady states. Had they done so, observed wage growth and house price growth would be just as persistent as observed population growth. Instead, observed wage growth and house price growth are characterized by low, even negative persistence (Table 3 Panel B).

Persistence arising from the gradual decline of durable housing is equally intuitive. Investment in housing is largely irreversible. Concurrent with negative changes to productivity and to quality of life, house prices may fall sufficiently to discourage any new investment. Thereafter, the local stock of housing will decline at the rate of its physical depreciation. But the low house prices also give an incentive for people to remain in the locality. Out migration ends up being proportional to housing's gradual decline.

Almost surely the slow decline of durable housing contributes to the persistence of local population flows. But if it were the main source of persistence, then transitions following *increases* in steady-state population would be very rapid. In other words, housings' durability potentially slows population declines but not population increases. Hence, only negative population growth would be characterized by persistence. Consistent with this, Glaeser and Gyourko [14] indeed find strong evidence that negative persistence exceeds positive persistence for a sample of 114 large U.S. municipalities during the 1970s and for a sample of 322 medium and large U.S. municipalities during the 1980s and 1990s.

What the Glaeser and Gyourko empirical result misses is the high persistence of positive population growth across "localities" — places where people live and work — that are geographically larger than municipalities. With U.S. *counties* as the unit of observation, empirical estimates strongly reject that negative persistence exceeds positive persistence. Table 4 shows results from regressing population growth on its lagged value and a constant for each decade, the 1910s through the 1990s. The specification differs from that underlying Table 3 in that the coefficients on both the intercept and lagged growth are allowed to differ depending on whether lagged growth is positive or negative. So for instance, $\hat{\rho}_{\gamma(value)}$ between the 1910s and the 1920s equals -1.08 for the 1,073 counties that lost population during the 1910s (column 2). That is, negative growth during the 1910s tended to become positive growth during the 1920s with similar magnitude to its earlier decline. But for the 1,771 counties that gained population during the 1910s, $\hat{\rho}_{\gamma(value)}$ equals 0.39. Between all subsequent decades, the persistence of growth for counties that were losing population is similarly estimated to be below the persistence of growth for counties that were gaining population. Only between the 1900s and the 1910s is the persistence of declining counties estimated to exceed the persistence of growing ones. A likely reconciliation of the present results with those of Glaeser and Gyourko is that positive population growth sprawls outside municipal borders.

5 Empirical Implications

The neoclassical local growth model has several important empirical implications. First is that *steady-state* local population density serves as an excellent measure of local contributions to representative-agent welfare. Local areas with high steady-state density are those with high local productivity and high local quality of life. Productivity and quality of life are the main sources of representative-agent welfare in the integrated macroeconomy. So the question, Why do some local areas have steady-state population densities so much higher than others? is quite close to the question, Why is steady-state per capita income so much higher in some nation-states than in others? For the latter question, steady-state per capita income is a direct proxy for representative-agent welfare. For the former question, steady-state population density reveals a preference ordering over the determinants of representative-agent welfare.

A second empirical implication is that the distribution of population across U.S. localities has been significantly away from its steady state during most of the twentieth century. This follows from the high observed persistence of net population flows but low observed persistence of local wage and house price growth. Hence, *observed* population density serves as a poor proxy for *steady-state* population density. But contrary to Greenwood et al. [17], the modeled transitions also show that observed wages and house sales prices may nevertheless be near their steady state. So the identifying assumption underlying the compensating differential empirical literature may not be so bad after all.

A third empirical implication is that cross-sectional regressions of local population growth on local characteristics can help to identify *changes* in the contributions from local characteristics to representative-agent welfare. Local areas that have experienced changes in local productivity and local quality of life are expected to subsequently experience population flows that are proportional to such changes and that persist over several decades.[6] So, for example, if a local characteristic is found to be positively correlated with local population growth, one can interpret this as an indication that the contribution from this characteristic to representative-agent welfare has increased. Alternatively, the local characteristic may itself be correlated with other local characteristics from which the contribution to representative-agent welfare has increased. Within the present modeling framework, the only other possible interpretation is that the local characteristic is correlated with something akin to a local capital shock. However, such a capital-shock interpretation becomes less likely when the positive correlation between the local characteristic and population growth is observed over a long period.

More generally, the neoclassical local growth model provides a framework for interpreting observed local growth rates. It identifies the types of possible shocks from which an observed pattern of local growth can arise. As a hypothetical example, consider a locality that is simultaneously experiencing positive population growth but negative wage growth. Static theory suggests that such a combination can arise only from an increase in labor supply. But the dynamic model shows that positive population growth accompanied by negative wage growth also characterizes a portion of the transition following an increase in local productivity, which is analogous to an increase in labor demand (Figure 2 with high labor mobility). Conversely, an increase in quality of life — analogous to an increase in labor

[6] The proportionality of population flows to the size of changes in productivity and quality of life is shown in the paper's supplemental materials.

supply — can lead to a long period during which population and wages are both increasing (the latter part of the transition in Figure 3).

As a first applied example, consider the large increase in the persistence of local U.S. population growth starting circa 1930 (Table 1 Panel A and Table 3 Panel A). One possible impetus is a large realignment, either discrete or gradual, of productivity across local areas. Such a productivity realignment might be linked to the huge increase in the size of the U.S. federal government accompanying New Deal legislation, World War II, and the Cold War. A different possible impetus for the increase in persistence is a large realignment, either discrete or gradual, of quality of life across local areas. Such a quality-of-life realignment might be linked to the viability of suburban living made possible by the increasing affordability of automobiles.

As a second example, consider the negative autoregressive persistence of income growth from the 1970s through the 1990s. One possible impetus is one or more shocks to local capital stock, for instance from the large increase in the price of oil during the 1970s. A different possible impetus is a large productivity shock that subsequently reversed itself, for instance from large swings in the terms of trade. Still another possible impetus is a realignment of quality of life across localities, for instance from middle-class perceptions of decaying urban school systems.

These last examples illustrate that in many cases, the neoclassical local growth model serves more as a framework for forming hypotheses than it does for distinguishing among them. But doing so is an important first step towards understanding what is driving observed local growth.

6 Conclusions

A neoclassical model of local growth is developed that embeds the static equilibrium underlying compensating differential theory as the steady state of a Ramsey-Cass-Koopmans growth model. Following small changes to local productivity or to local quality of life, even very small frictions to labor and capital mobility suffice to cause highly persistent population flows. Wages and house prices, in contrast, jump most of the way to their new steady states.

The model suggests several important theoretical lines of research. One is a richer modeling of local steady states. The present setup assumes a constant flow supply of housing. Instead, housing could be modeled as a nontraded durable good produced from land, labor, and capital. A second theoretical line is an explicit modeling of the sources of labor and capital mobility. For example, the labor and capital frictions might arise from bottlenecks in the construction of housing and public infrastructure. A third theoretical line is to distinguish between population and employment. In reality, capital shocks are clearly absorbed in part by involuntary unemployment rather then emigration. A fourth theoretical line is to allow for some heterogeneity among local residents. For example, observed growth of local income may reflect sorting. More generally, the neoclassical local growth model provides a framework in which to embed theories on the determinants of local productivity and quality of life.

From an empirical perspective, the model suggests that cross-sectional regressions of local population growth on local characteristics can help identify the partial correlates of past and present changes to local productivity and local quality of life. Doing so should make a significant contribution towards understanding the actual determinants of productivity and quality of life. Additionally, the model shows that the compensating-wage-differential literature's identifying assumption that wages and house prices are at their steady state may be approximately correct notwithstanding persistent population flows. Finally, the model identifies types of possible shocks from which an observed pattern of local growth can arise.

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Table 1: Cross-Sectional Persistence of Local Growth

A. Population Growth (1900–2000): pairwise raw correlation of population growth rates by decade, 1900–2000, for continental U.S. counties.

	1900s	1910s	1920s	1930s	1940s
1900s	1				
1910s	0.28	1			
1920s	0.50	0.11	1		
1930s	-0.03	0.00	0.15	1	
1940s	0.20	0.18	0.40	0.35	1
1950s	0.10	0.12	0.28	0.35	0.69
1960s	-0.13	0.00	0.04	0.31	0.44
1970s	-0.10	-0.04	-0.03	0.33	0.16
1980s	-0.11	-0.03	0.01	0.29	0.28
1990s	-0.15	-0.01	-0.12	0.24	0.12

	1950s	1960s	1970s	1980s	1990s
1950s	1				
1960s	0.58	1			
1970s	0.27	0.52	1		
1980s	0.40	0.61	0.70	1	
1990s	0.22	0.49	0.68	0.72	1

B. Median Family Income Growth (1950–2000): pairwise raw correlation of median family income growth rates by decade, 1950–2000, for continental U.S. counties.

	1950s	1960s	1970s	1980s	1990s
1950s	1				
1960s	0.20	1			
1970s	0.09	0.21	1		
1980s	0.20	0.22	-0.31	1	
1990s	0.00	0.22	0.19	-0.20	1

C. Median House Sales Price Growth (1950–2000): pairwise raw correlation of median house sales price growth rates by decade, 1950–2000, for continental U.S. counties.

	1950s	1960s	1970s	1980s	1990s
1950s	1				
1960s	0.00	1			
1970s	0.13	-0.04	1		
1980s	0.08	0.35	-0.24	1	
1990s	0.02	0.03	0.22	-0.47	1

Table 2: Comparative Statics

Steady-State Response of Endogenous
Variables to Variation in Exogenous Parameters

	L_s^*, $value_s^*$	k_s^*, w_s^*	q_s^*
A_s	$+$	$+$	0
$quality_s$	$+$	0	0
$b_{K,s}$	$-$	$-$	$+$
b_L	0	0	0

Note: Comparative statics for L_s^* and $value_s^*$ hold $assets_s^*$ constant. As discussed in the main text, $assets_s^*$ depends on the history of small-economy shocks. The paper's supplemental materials discuss the effects of varying $assets_s^*$.

Table 3: Autoregressive Persistence of Local Growth

A. Population

	(1) **Pop. Growth 1910s**	(2) **Pop. Growth 1920s**	(3) **Pop. Growth 1930s**	(4) **Pop. Growth 1940s**	(5) **Pop. Growth 1950s**	(6) **Pop. Growth 1960s**	(7) **Pop. Growth 1970s**	(8) **Pop. Growth 1980s**	(9) **Pop. Growth 1990s**
Population Growth Previous Decade	**0.14**	0.14	**0.08**	**0.47**	**0.75**	**0.45**	**0.53**	**0.59**	**0.67**
	(0.03)	(0.14)	**(0.02)**	**(0.06)**	**(0.03)**	**(0.03)**	**(0.04)**	**(0.03)**	**(0.02)**
Obs.	2,696	2,844	3,014	3,060	3,062	3,064	3,064	3,067	3,067
R^2	0.08	0.01	0.02	0.12	0.47	0.33	0.27	0.49	0.52

B. Median Family Income and Median House Sales Price

	(1) **Income Growth 1960s**	(2) **Income Growth 1970s**	(3) **Income Growth 1980s**	(4) **Income Growth 1990s**	(5) **Sales Price Growth 1960s**	(6) **Sales Price Growth 1970s**	(7) **Sales Price Growth 1980s**	(8) **Sales Price Growth 1990s**
Growth Previous Decade	**0.16**	**0.17**	**-0.29**	**-0.15**	0.00	-0.05	**-0.31**	**-0.35**
	(0.03)	**(0.02)**	**(0.03)**	**(0.02)**	(0.03)	(0.03)	**(0.07)**	**(0.03)**
Obs.	3,005	3,049	3,065	3,067	2,540	2,541	3,063	3,066
R^2	0.04	0.05	0.09	0.04	0.00	0.00	0.06	0.22

Tables show results from regressing specified growth rate on a constant and the same growth rate for the previous decade. Coefficient standard errors in parentheses are robust to spatial correlation with a weighting that declines quadratically to zero for counties with centers 200 km apart (Conley [10], Rappaport [26]). Bold type signifies coefficients statistically different from zero at the 0.05 level. For Panel B, "Growth Previous Decade" is median family income growth for columns 1–4 and median house sales price for columns 4–8.

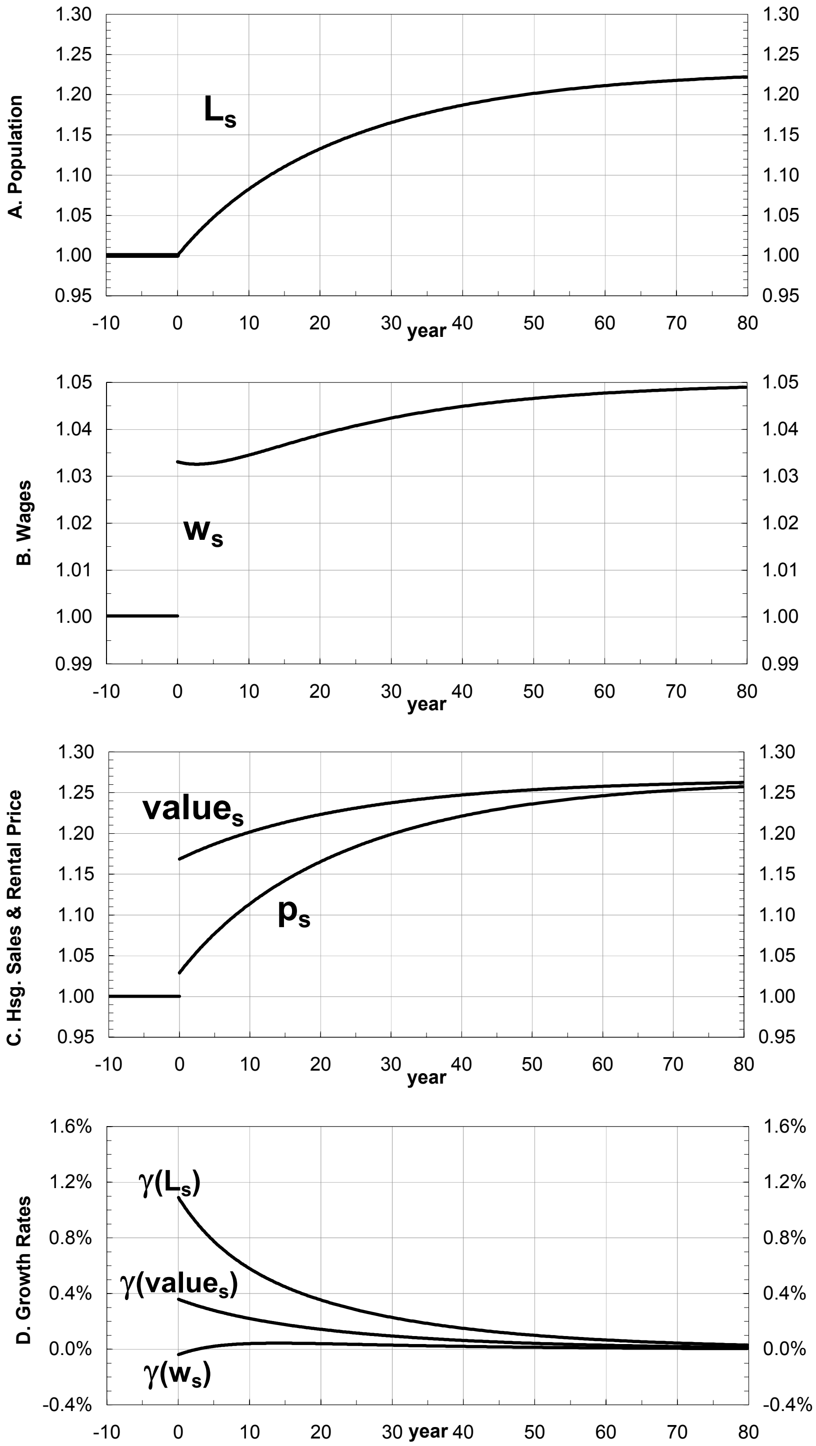
Table 4: Autoregressive Persistence with Different Data Generating Processes for Growing and Declining Counties

A. Population Growth

	(1) **Pop. Growth 1910s**	(2) **Pop. Growth 1920s**	(3) **Pop. Growth 1930s**	(4) **Pop. Growth 1940s**	(5) **Pop. Growth 1950s**	(6) **Pop. Growth 1960s**	(7) **Pop. Growth 1970s**	(8) **Pop. Growth 1980s**	(9) **Pop. Growth 1990s**
Growth Previous Decade:									
neg. spline	**0.43**	**-1.08**	**-0.18**	-0.05	**0.51**	**0.36**	**0.22**	**0.34**	**0.56**
	(0.19)	**(0.42)**	**(0.07)**	(0.14)	**(0.07)**	**(0.07)**	**(0.10)**	**(0.08)**	**(0.06)**
pos. spline	**0.09**	**0.39**	**0.08**	**0.46**	**0.74**	**0.38**	**0.58**	**0.59**	**0.63**
	(0.04)	**(0.06)**	**(0.03)**	**(0.08)**	**(0.06)**	**(0.04)**	**(0.05)**	**(0.03)**	**(0.04)**
Obs.									
neg. spline	748	1,073	1,248	959	1,513	1,528	1,352	538	1,399
pos. spline	1,948	1,771	1,766	2,101	1,549	1,536	1,712	2,529	1,668
R^2	0.12	0.17	0.04	0.15	0.48	0.34	0.29	0.49	0.52
F-Stat (No Growth Spline)	15.4	512.3	36.9	46.6	22.7	0.4	49.3	11.3	2.3
Prob > F	0.00	0.00	0.00	0.00	0.00	0.52	0.00	0.00	0.13

Coefficient standard errors in parentheses are robust to spatial correlation with a weighting that declines quadratically to zero for counties with centers 200 km apart (Conley [10], Rappaport [26]). Bold type signifies coefficients statistically different from zero at the 0.05 level. F-statistics compare the displayed specification versus one that allows separate positive and negative intercepts but constrains the coefficient on lagged growth to be identical regardless of previous growth.

Figure 1: Dynamics from a Positive Productivity Change

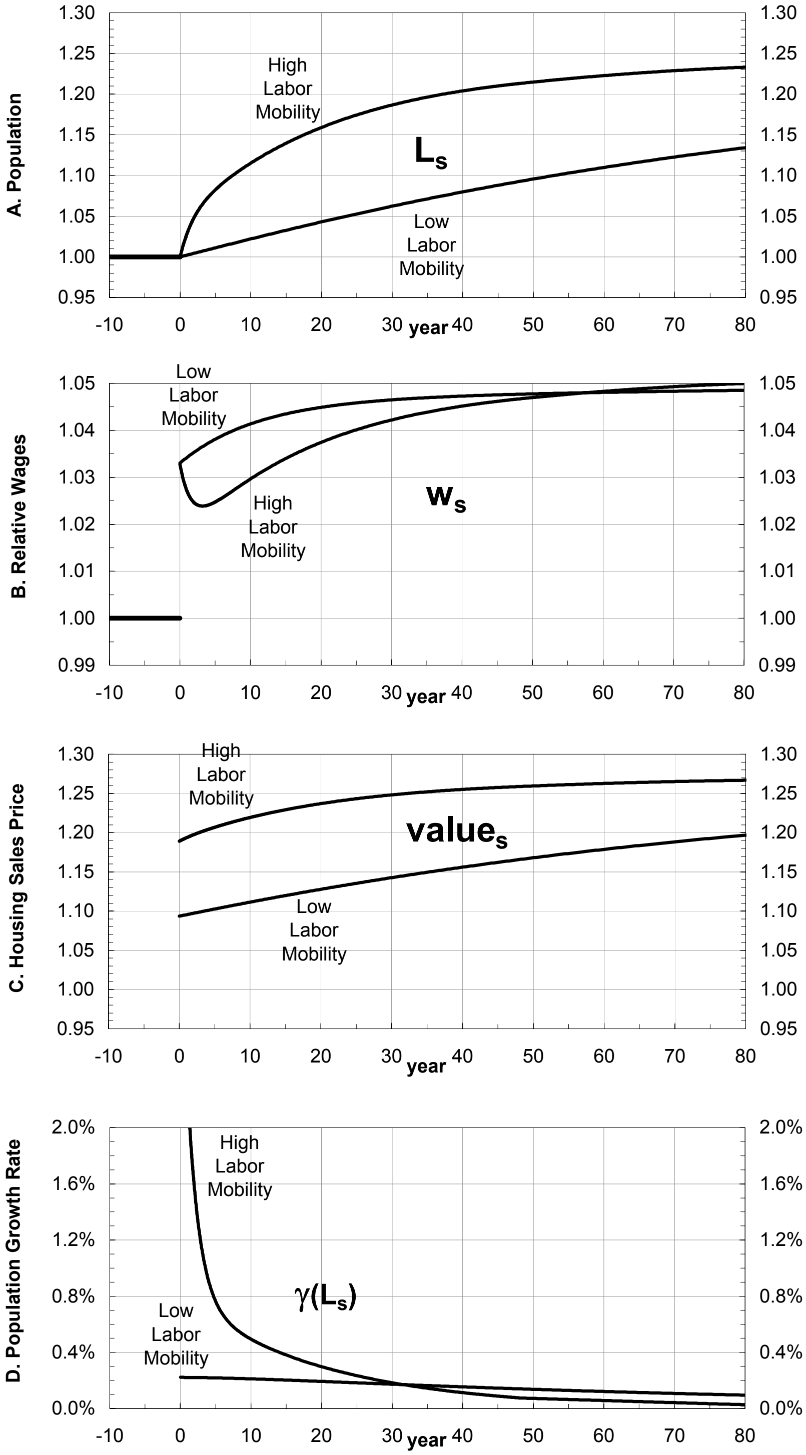


Calibration

Figure assumes an increase in small-economy total factor productivity such that steady-state small-economy wages increase by 5%. With a one-third capital factor income share, this implies a 3.3% rise in TFP.

Capital Share	$\alpha = 0.33$
Capital Depreciation Rate	$\delta = 0.06$
Housing Share	$\zeta = 0.15$
Time Preference	$\rho = 0.03$
Steady-State Shadow Value of Capital	$q_K^* = 1.48$
Net Migration Response to 1% Wealth Differential	$\mu = 2$

Figure 2: High vs. Low Labor Mobility
Dynamics from a Positive Productivity Change

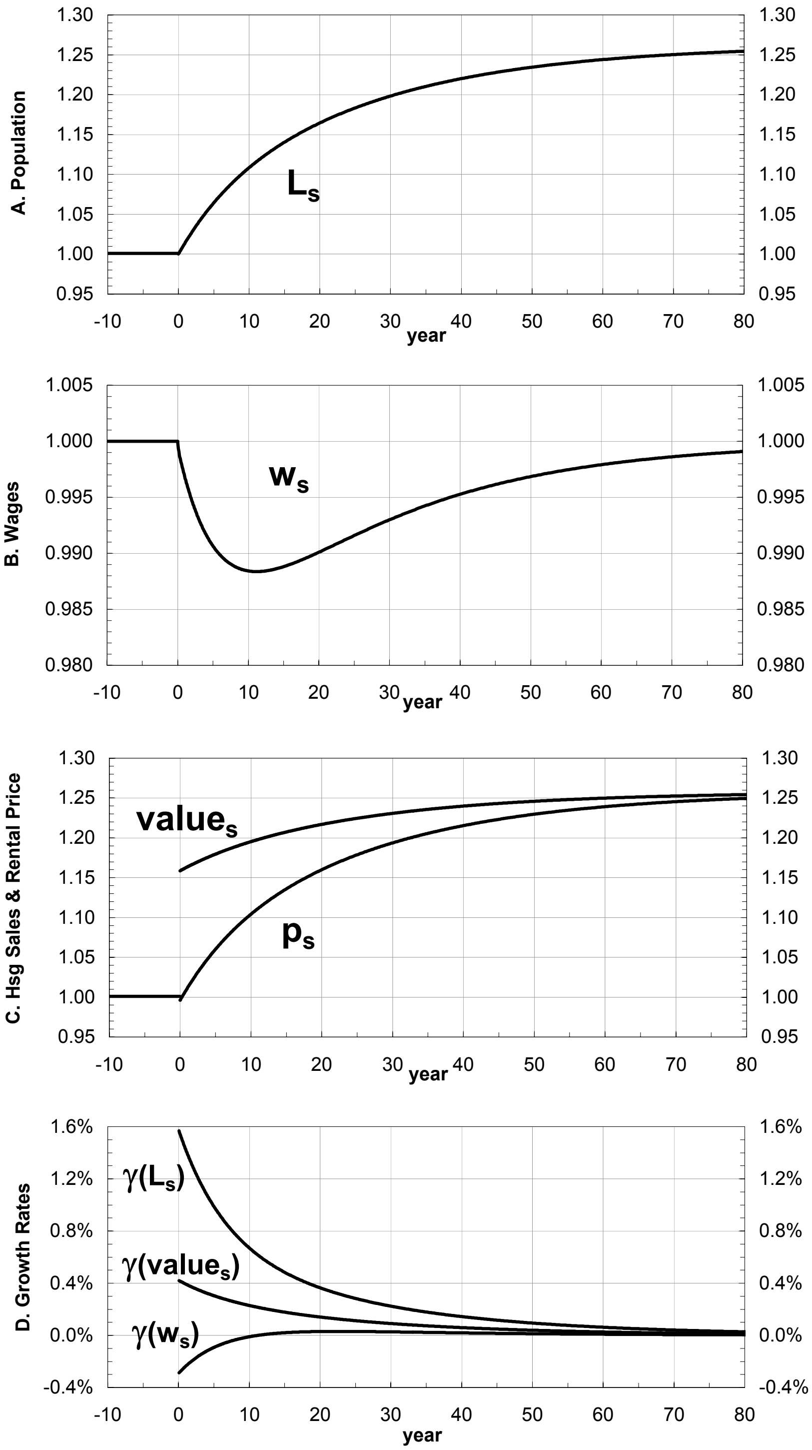


Calibration

Figure assumes an increase in small-economy productivity such that steady-state small-economy wages increase by 5%. With a one-third capital share, this implies a 3.3% rise in TFP. Except for labor mobility, parameters repeated below are the same as in Figure 1.

Capital Share	$\alpha = 0.33$
Capital Depreciation Rate	$\delta = 0.06$
Housing Share	$\zeta = 0.15$
Time Preference	$\rho = 0.03$
Steady-State Shadow Value of Capital	$q_K^* = 1.48$
Net Migration Response to 1% Wage Differential	$\mu_{Low} = 1/8$ $\mu_{High} = 32$

Figure 3: Dynamics from a Positive Quality of Life Change

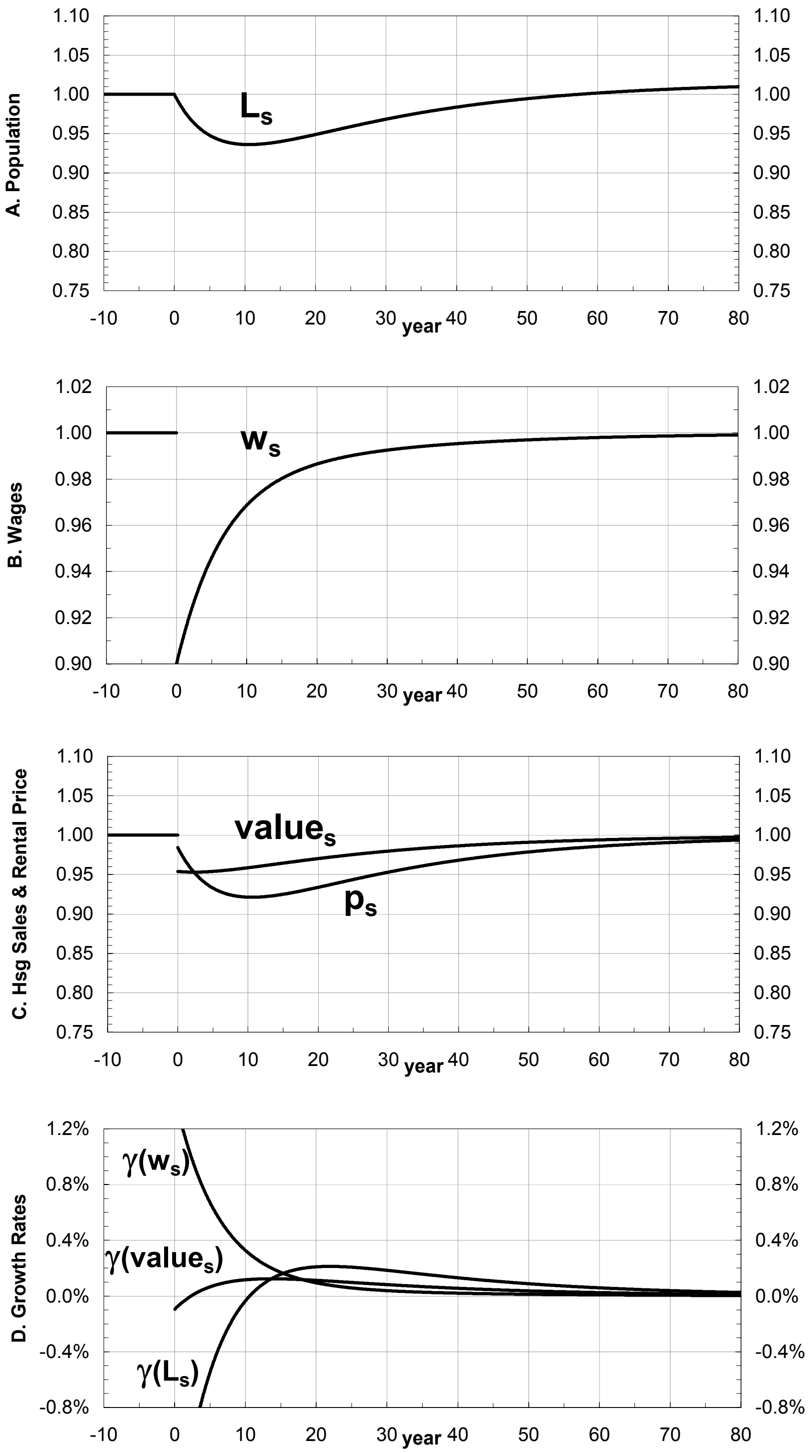


Calibration

Figure assumes an increase in small-economy quality of life equivalent to 3.5% of large-economy consumption. Parameters repeated below are the same as in Figure 1.

Capital Share	$\alpha = 0.33$
Capital Depreciation Rate	$\delta = 0.06$
Housing Share	$\zeta = 0.15$
Time Preference	$\rho = 0.03$
Steady-State Shadow Value of Capital	$q_K{}^* = 1.48$
Net Migration Response to 1% Wealth Differential	$\mu = 2$

Figure 4: Dynamics from a Negative Capital Shock



Calibration

Figure assumes a shock to initial small-economy physical capital stock such that initial small-economy wages are 90% their steady-state level. Parameters repeated below are the same as in Figure 1.

Capital Share	$\alpha = 0.33$
Capital Depreciation Rate	$\delta = 0.06$
Housing Share	$\zeta = 0.15$
Time Preference	$\rho = 0.03$
Steady-State Shadow Value of Capital	$q_K^* = 1.48$
Net Migration Response to 1% Wealth Differential	$\mu = 2$