WHY ARE POPULATION FLOWS SO PERSISTENT?

Jordan Rappaport

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Rappaport e-mail: jordan.m. rappaport@kc.frb.org

Abstract

A neoclassical model of local growth is developed by integrating the static equilibrium underlying compensating di! erential theory as the long run steady state of a Ramsey-Cass-Koopmans growth model. Numerical results show that even very small frictions to both labor and capital mobility along with small changes in either underlying local productivity or local quality of life together su" ce to cause highly persistent population flows. Wages and house prices, in contrast, approach their steady-state levels relatively quickly. Summary empirics suggest that circa #930, the United States experienced a large shock which redistributed productivity across its localities; that circa #960, quality of life became more important in driving U.S. population flows; and that circa #970, the United States experienced a shock which disproportionately a! ected the installed capital base of some localities relative to others but which left underlying relative productivity and quality of life unchanged.

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JEL Classifications: O4#, R##, F43, J6#

1 Introduction

Persistent population flows strongly characterize local growth within the United States during the 20th century. Local areas which 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 period 1909 to 1953, for net migration over the period 1900 to 1987, and for employment growth over the period 1950 to 1990 (Borts, 1960; Barro and Sala-i-Martin, 1991; Blanchard and Katz, 1992). Across U.S. cities, high persistence has been documented for population growth over the period 1950 to 1990 (Glaeser, Scheinkman, and Shleifer, 1995). And across U.S. counties, Table 1 documents moderately high persistence for population growth starting around 1930. Why are population flows so persistent?

Per capita income growth and house price growth, on the other hand, show positive serial correlation between some adjacent decades but negative serial correlation between others (Table 2). Correspondingly, the cross correlations among population flows, income growth, and house price growth vary tremendously across decades (Table 3). While different combinations of labor supply and demand shifts can doubtlessly "explain" such differences, how do we reconcile the varied patterns with the persistent population flows?

Finally, Table 4 documents that population flows towards areas with high house prices. This result might be expected if house prices proxy for wages or employment opportunities; but population flows towards high house prices even after extensively controlling for both initial wages and employment density. Another possible explanation is that intrinsically forward-looking house *sales* prices are just anticipating future population inflows; but population similarly flows towards high house *rental* prices. What is going on here?

Addressing these questions requires an explicitly dynamic framework of local economic growth. The present paper develops exactly such a framework by integrating the static equilibrium underlying compensating differential theory (Rosen, 1979; Roback, 1982; Blomquist et. al., 1988; Gyourko and Tracy, 1989, 1991) as the long run steady state of a Ramsey-Cass-Koopmans growth model (Ramsey, 1926; Cass, 1965; and Koopmans, 1965).

Numerical results show that even very small frictions to both labor and capital mobility along with small changes in either underlying local productivity or local quality of life together suffice to cause highly persistent population flows. Wages and house prices, in contrast, approach their steady-state levels relatively quickly because they are able to "jump" concurrent with changes to productivity and to quality of life. Such jumps can account both for the observed low serial correlations of per capita income growth and house price growth as well as for the observed population flows toward high house prices. Furthermore, this dichotomy between the slow speed at which population approaches its steady state and the rapid speeds at which wages and house prices do so suggests that contrary to Greenwood et al. (1991), persistent population flows do not necessarily contradict the compensating differential literature's identifying assumption that wages and house prices are at their long run steady states.

The paper proceeds as follows. Section 2 lays out the formal assumptions and basic results of a neoclassical theory of local growth. Section 3 describes the numerically derived impulse response functions from shocks to local productivity, local quality of life, and local capital stock; a last subsection briefly discusses the plausibility of the compensating differential empirical framework's identifying assumption that wages and house prices are near their steady state levels. Section 4 uses the impulse response functions to interpret some summary empirics on local economic growth across U.S. states and counties. The empirics suggest that circa 1930, the United States experienced a large shock which redistributed productivity across its localities; that circa 1960, quality of life became more important in driving U.S. population flows; and that circa 1970, the United States experienced a shock which disproportionately affected the installed capital base of some localities relative to others but which left underlying relative productivity and quality of life unchanged. A last section concludes.

2 A Neoclassical Model of Local Growth

The extended Ramsey-Cass-Koopmans framework developed herein assumes a large number of "localities" which together constitute an integrated macroeconomy. A locality represents a well-defined market both for labor and for nontraded goods; it may correspond to a city or region within a nation state or even, as perhaps suggested by the European Union, to a nation state itself. Being small, a locality can take tradable output prices and interest rates as given; conditions within the locality itself determine local nontradable prices, local wage levels, and local population.

Localities differ with respect to *exogenous* underlying productivity and quality of life.

Productivity captures local public goods which enter as arguments in local firms' production functions; productivity enhancing local attributes might correspond to natural harbors, navigable rivers, and central locations. Quality of life captures local public goods which enter as arguments in local residents' utility functions; quality-of-life enhancing local attributes might correspond to moderate climates, scenic vistas, and natural recreational endowments.

In a long run steady state, each of the localities which together make up the integrated macroeconomy must offer optimizing individuals an identical level of utility and optimizing firms an identical level of profits. This condition is exactly the same as the identifying assumption underlying the compensating wage and house price differential literature. But frictions to labor and capital mobility effect an extended equilibrium transition path during which rents will be associated with living and owning installed capital in certain localities relative to others. Herein I will focus on the dynamics experienced by a single such locality while assuming that the integrated rest-of-world economy is already at its steady state.

A final change to the standard Ramsey-Cass-Koopmans setup is that, in addition to consumption of tradable output, individual utility is augmented to include consumption of a locally-produced nontradable good. Herein, I simply assume a constant flow supply of the nontradable good; a natural interpretation is that it corresponds to housing services. To the extent that production of the tradable good is capital intensive relative to production of the nontradable good, nontradable consumption lessens the incentive for emigration from capital poor localities. Equally important, the inclusion of a fixed resource such as housing services captures that a locality is limited in scope; without a fixed resource constraint, all individuals and firms within the integrated macroeconomy end up locating in the locality with the highest combination of productivity and quality of life.

Various elements of this neoclassical local growth theory already exist within the economics literature. In particular, Mueser and Graves (1995) contend that the instantaneous equating of utility and profits across localities assumed by static theories of locational choice is unrealistic; instead, they argue that population and firm locational movements must be proportional to utility and profit differentials. More formally, Braun (1993) 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.

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 seven subsections: individual utility functions and behavior, firm production functions and behavior, land price determination, characteristics of the integrated macroeconomy steady state, the decision by individuals to migrate, transitional dynamics, and the characteristics of the local steady state.

2.1 Individuals

I assume a small open economy, i, inhabited by a continuum of individuals with collective mass $L_i(t)$. These individuals need not be identical; but if they are not, I must adopt a structure sufficient to allow for the admittance of a representative local agent. Herein, such structure is indeed present as are assumptions that insure that all locally-residing individuals are identical; per capita variables can thus be interpreted as pertaining either to a representative agent or to all local individuals.

A key difference from the standard neoclassical framework is that in addition to the consumption of private output goods, individuals also derive utility from the consumption of private housing services, $n_i(t)$, and non-congestible quality-of-life amenities, $\text{quality}_i(t)$. Lifetime utility in locality i is given by,

$$U_i(t) = \int_t^\infty \left((1-\zeta)\log\left(c_i\left(s\right)\right) + \zeta\log\left(n_i\left(s\right)\right) + \eta\log\left(\text{quality}_i\left(s\right)\right)\right)\mathrm{e}^{-\rho(s-t)}\,\mathrm{d}s \qquad (1)$$

As in the neoclassical model, individuals face an instantaneous asset accumulation constraint. To ease exposition, I assume absentee landlords. While such an assumption clearly maps poorly to actual local housing ownership, relaxing it is expected to reinforce the present system's dynamics. With the output good as numeraire and $p_i(t)$ as the rental price of housing services, asset accumulation is given by,

$$\frac{\mathrm{d}}{\mathrm{d}t}\text{assets}_i\left(t\right) = r\cdot\text{assets}_i\left(t\right) + w_i\left(t\right) - c_i\left(t\right) - p_i\left(t\right)n_i\left(t\right) \qquad (2)$$

Individuals face the lifetime budget constraint that the net present value of their output and housing-service consumption not exceed their current wealth which is itself the sum of their asset wealth and the net present value of their wages.

$$\int_t^\infty \left(c_i\left(s\right) + p_i\left(t\right)n_i\left(s\right)\right)e^{-r(s-t)}\,\mathrm{d}s \leq \text{total\_wealth}_i\left(t\right) \qquad (3)$$

$$\text{total\_wealth}_i\left(t\right) \equiv \text{assets}_i(t) + \text{labor\_wealth}_i\left(t\right)$$

$$\text{labor\_wealth}_i(t) \equiv \int_t^\infty w_i(s)\,\mathrm{e}^{-r(s-t)}\mathrm{d}s$$

Setting up and solving for individuals' optimal behavior, at any point in time they will devote the fraction ρ of their total wealth on current consumption; of this, they will spend the fraction $(1-\zeta)$ on the tradable output good and the remaining fraction ζ on housing services. The actual quantity of housing services consumed depends on its rental price, the level of which will be determined endogenously.

$$c_i(t) = \rho(1-\zeta)\,\text{total\_wealth}_i(t) \tag{4a}$$

$$n_i(t) = \frac{\rho\zeta\text{total\_wealth}_i(t)}{p_i(t)} \tag{4b}$$

The additive separable utility form in (1) along with the optimal output and housing consumption functions, (4a) and (4b), allow for an easy decomposition of individuals' lifetime utility into a function, $f(\cdot)$, whose arguments are exogenous to locality i, along with elements that depend separably on individuals' wealth, the time path of local housing rental prices, and the time path of local quality of life.

$$\begin{aligned} U_i(t) &= \mathrm{f}(\rho,\zeta,r) + \frac{\log(\text{total\_wealth}_i(t))}{\rho} - \zeta\int_t^\infty \log(p_i(s))\,\mathrm{e}^{-\rho(s-t)}\mathrm{d}s \qquad (5a) \\ &\quad + \eta\int_t^\infty \log(\text{quality}_i(s))\,\mathrm{e}^{-\rho(s-t)}\mathrm{d}s \\ U_i(t) &= \mathrm{f}(\rho,\zeta,r) + U_{\text{wealth},i}(t) + U_{\text{price},i}(t) + U_{\text{quality},i}(t) \qquad (5b) \end{aligned}$$

Since the economy-wide adding up constraint that the sum of individuals' asset wealth must equal the aggregate capital stock does not apply to our locality, it becomes necessary to track the evolution of local asset wealth. Assuming for the moment no effect on mean asset wealth from migration into or out of the locality, (2), (4a) and (4b) imply that per capita asset wealth evolves according to,

$$\frac{\mathrm{d}}{\mathrm{d}t}\text{assets}_i(t) = w_i(t) + (r-\rho)\,\text{assets}_i(t) - \rho\cdot\text{labor\_wealth}_i(t) \tag{6}$$

As discussed below, I assume that anyone migrating into locality i has the same contemporary asset wealth as the current mean in i which implies that (6) will hold in equilibrium.[1]

[1] The main importance of asset wealth is its role in determining local housing prices as shown in (10) below. Given the homothetic specification of utility in (1), what matters for housing prices is *mean* local asset wealth. Allowing for individuals with different levels of asset wealth, the evolution of mean asset wealth is the same as in (6) along with the addition of a term that captures the difference between current mean asset wealth and the asset wealth of current migrants.

2.2 Firms

Within the locality are a number of firms, each with access to a constant-returns-to-scale (CRS) production function, and which maximize the net present value of future cash flows. As CRS implies an indeterminate firm size, I write instead the collective local production, capital accumulation, and value functions as,

$$Y_i(t) = A_i(t) K_i(t)^{\alpha} \left(L_i(t) \mathrm{e}^{xt} \right)^{1-\alpha} \tag{7}$$

$$\frac{\mathrm{d}}{\mathrm{d}t} K_i(t) = I_i(t) - \delta K_i(t) \tag{8}$$

$$V_i(t) = \int_t^{\infty} \left(Y_i(s) - w_i(s) L_i(s) - I_i(s) \left(1 + \frac{bK,i}{2} \left(\frac{I_i(s)}{K_i(s)} \right) \right) \right) \mathrm{e}^{-r(s-t)} \mathrm{d}s \tag{9}$$

$A_i(t)$ and x respectively capture locality-specific total factor productivity and the economy-wide rate of exogenous labor-augmenting technological progress. Although housing services are excluded from the production function, firms still "care" about house prices as these affect the wage firms need to pay to attract workers.[2] Along the lines of Abel (1982) and Hayashi (1982), (9) assumes the *average* cost of installing capital to be a linear function of the rate of gross investment, $\frac{b_{K,i}}{2} \frac{I_i(t)}{K_i(t)}$. The parameter $b_{K,i}$ captures the magnitude of the locality-specific capital installation cost. Letting $b_{K,i}$ go to zero captures a locality in which capital can be costlessly installed and uninstalled. The solution to firms' maximization problem is standard and so is omitted.

2.3 Housing Price Determination

Local housing services are assumed to flow at the fixed aggregate rate, $N_i(t)$. With housing-service supply permanently fixed and population instantaneously fixed, mean per capita housing-service consumption, $n_i(t)$, must equal $\frac{N_i}{L_i(t)}$. The current rental price of housing services, $p_i(t)$, is just the price which realizes this level of housing-service demand. Using (4b) and the definition of total wealth, the price of housing services which clears the market can be written as,

$$p_i(t) = \frac{\rho \zeta}{N_i} L_i(t) \cdot \left(\text{assets}_i(t) + \text{labor\_wealth}_i(t) \right) \tag{10}$$

[2] The exclusion of housing services from the production function is the only way in which the local growth system's steady state differs from the compensating differential literature's equilibrium. With housing services as a productive input, output denominated steady-state wages vary inversely with quality of life. Also, the positive relationship between steady-state population density and productivity discussed below may fail as firms' increased demand for housing services crowds out local residents (Rappaport 1999a).

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

$$\text{value}_i(t) \equiv \int_t^\infty p_i(s)\ \mathrm{e}^{-r(s-t)}\mathrm{d}s$$

2.4 Integrated Macroeconomy Steady State

In contrast to locality i , the remaining rest-of-world economy is assumed to be in its long run steady state. That locality i is small and the rest of the world is large allows for such a dichotomy.

The *row* steady state is characterized by standard neoclassical results for a closed economy. The production and adjustment cost functions together imply that capital's shadow value equals its average value. Net borrowing among *row* individuals is zero and so mean *row* asset wealth must exactly equal the value of *row* installed capital, $\text{assets}_{row}(t) = q_{K,row}k_{row}(t)$. The interest rate which effects such an equilibrium is given by the sum of individuals rate of time preference and the rate of technological progress, $r = \rho + x$. The equilibrium shadow value of capital, $q_{K,row}$, is exactly that which induces a rate of investment consistent with a constant level of capital per effective worker:

$$q_{K,row} = 1 + (x + \delta)\ b_{K,row} \tag{11}$$

In a long run steady state, each of the system variables grows at the exogenous rate of technological progress.

$$\frac{\frac{\mathrm{d}}{\mathrm{d}t}w_{row}(t)}{w_{row}(t)} = \frac{\frac{\mathrm{d}}{\mathrm{d}t}\text{labor\_wealth}_{row}(t)}{\text{labor\_wealth}_{row}(t)} = \frac{\frac{\mathrm{d}}{\mathrm{d}t}k_{row}(t)}{k_{row}(t)} = \frac{\frac{\mathrm{d}}{\mathrm{d}t}\text{assets}_{row}(t)}{\text{assets}_{row}(t)} = \frac{\frac{\mathrm{d}}{\mathrm{d}t}p_{row}(t)}{p_{row}(t)} = x \tag{12}$$

2.5 The Decision to Migrate

Analogous to the installation cost associated with capital investment, I assume a labor mobility friction proportional to net population flow rates. To motivate this, consider rental prices for one-way do-it-yourself moving trucks. Supposing a net flow of individuals from East to West, demand for rental trucks will be high in the East while their supply will be high in the West. The higher the net flow west, the higher westbound prices need to be to equilibrate supply and demand. Conversely, rental companies may be willing to subsidize eastbound movers in order to redeploy their fleets. It is hard to imagine such moving prices effecting large frictions, and so the calibrations below will show results for net migration frictions which are "very small".

Frictions proportional to the rate of net migration might arise from several other sources. For instance, relaxing the assumption of a fixed flow supply of housing services, housing stock could be modeled with an installation cost exactly the same as that for physical capital. While such a setup would admit discrete infinite-rate population flows immediately following shocks, additional net population flows would accompany transitional expansions and contractions of housing stock. Endogenizing the labor mobility friction is a priority for future research.

Of course, numerous other labor mobility frictions may arise which are not proportional to net flows. Large gross flows may increase costs by lengthening expected job search time. Alternatively, large gross flows may decrease costs by facilitating a thicker market for services demanded by movers (e.g., the very existence of one-way do-it-yourself rental truck companies). For departure-destination location pairs, information transmission may make costs decreasing in the sum over previous gross flows. Such alternative frictions are unlikely to be completely orthogonal to net flows, and therefore they may very well modify local growth dynamics. Even so, it seems quite reasonable to believe a "net" friction proportional to net population flows will remain. Again it is worth emphasizing that the numerical results below include calibrations with "very small" labor mobility frictions.

I model the labor mobility friction as a utility cost proportional to the net flow rates in both the departing and receiving locality.[3] Letting arrows represent the direction of net migration, the utility cost can be formalized as,

$$U^{\text{cost}}_{i \to row} = b_{L,row} \frac{\frac{\mathrm{d}}{\mathrm{d}t} L_{row}(t)}{L_{row}(t)} - b_{L,i} \frac{\frac{\mathrm{d}}{\mathrm{d}t} L_i(t)}{L_i(t)} = -b_{L,i} \frac{\frac{\mathrm{d}}{\mathrm{d}t} L_i(t)}{L_i(t)} \tag{13a}$$

$$U^{\text{cost}}_{row \to i} = -b_{L,row} \frac{\frac{\mathrm{d}}{\mathrm{d}t} L_{row}(t)}{L_{row}(t)} + b_{L,i} \frac{\frac{\mathrm{d}}{\mathrm{d}t} L_i(t)}{L_i(t)} = b_{L,i} \frac{\frac{\mathrm{d}}{\mathrm{d}t} L_i(t)}{L_i(t)} \tag{13b}$$

The second set of equalities follows from the largeness assumption about *row*.[4]

In an equilibrium, the flow between i and row must be such that the marginal migrant be 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

[3] 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 will effect nearly identical dynamics as long as it rises at the rate of exogenous technological progress, for instance if costs were proportional to real wages.

[4] The flow out of or into row is just the negative of the flow into or out of i, and L_{row} is an order of magnitude greater than L_i; as long as $\frac{\mathrm{d}}{\mathrm{d}t} L_i(t)$ is of the same order of magnitude as $L_i(t)$, $\frac{\frac{\mathrm{d}}{\mathrm{d}t} L_i(t)}{L_{row}} \approx 0$.

destination location. Defining $\mathrm{d}U_i(t)$ as the utility differential associated with living in i,

$$\mathrm{d}U_i(t) \equiv U_i(t) - U_{row}(t)$$

It follows that the rate of net migration *into* locality i is given by,

$$\frac{\frac{\mathrm{d}}{\mathrm{d}t} L_i(t)}{L_i(t)} = \frac{\mathrm{d}U_i(t)}{b_{L,i}} \tag{14}$$

While all agents in both i and *row* are assumed to be identical with regards to their inherent characteristics (there are no high-skilled or low-skilled individuals), where they may differ is with regards to their asset wealth; moreover this is a difference that they retain should they choose to migrate. Let $\mathrm{d}U_i(t) > 0$ so that there is a positive utility differential associated with living in i and hence a net migration flow from *row* to i. The largeness assumption on *row* obviates the need to distinguish between marginal and average migrants (i.e., *row* has a sufficient number of residents with any given asset wealth level that all time-t migrants can be assumed to be identical). A "marginal migrant" from *row* into i is assumed to have asset wealth equivalent to the contemporary mean in i. As all residents in i are assumed to start with identical asset wealth prior to any shocks, the same definition works when there is a net flow from i to *row*.

Consistent with Tiebout's (1956) hypothesis that migration sorts a heterogenous population into more homogenous sub-populations, migration in the present case sorts individuals according to their asset wealth. A possible justification is that in the real world, zoning laws place limits on the quantity of housing services that individuals can buy; having the same asset wealth as current residents, in-migrants desire the same quantity of housing services.[5] Note that in an important sense this assumption of Tiebout wealth sorting binds: the lower an individual's asset wealth, the greater their utility gain for a given increase in labor wealth. And so when utility is (temporarily) higher in i than in *row* due to higher labor wealth, it is those individuals in *row* with the lowest asset wealth who have the greatest incentive to migrate.

The main result emphasized herein — the persistence of population flows following small shocks to local productivity and local quality of life — does *not* depend on such Tiebout wealth sorting. Driving the persistence result is the complementarity between

[5] More problematic is reconciling such a zoning explanation with the modeling of in-migrants as raising aggregate demand for housing services thereby causing current residents to decrease their housing-service consumption (but not expenditure).

capital and labor: a friction-induced persistent flow by one factor effects a persistent flow by the other factor which then feeds back to the first. This persistence occurs regardless of the specific assumption made with respect to the asset wealth of migrants. (Also see Appendix B.)

The utility differential associated with living in i relative to *row* can be decomposed using (5b) where each of the right-hand-side terms is defined analogously to $\mathrm{d}U_i(t)$:

$$\mathrm{d}U_i\left(t\right) = \mathrm{d}U_{\text{wealth},i}\left(t\right) + \mathrm{d}U_{\text{price},i}\left(t\right) + \mathrm{d}U_{\text{quality},i}\left(t\right) \tag{15}$$

Using (5a) and the definition of total wealth, these in turn can be written as,

$$\mathrm{d}U_{\text{wealth},i}\left(t\right) = \frac{1}{\rho}\log\left(\frac{\text{labor\_wealth}_i\left(t\right) + \text{assets}_i\left(t\right)}{\text{labor\_wealth}_{row}\left(t\right) + \text{assets}_i\left(t\right)}\right) \tag{16a}$$

$$\mathrm{d}U_{\text{price},i}\left(t\right) = \zeta\int_t^\infty \log\left(\frac{p_{row}\left(s\right)}{p_i\left(s\right)}\right)\mathrm{e}^{-\rho(s-t)}\mathrm{d}s \tag{16b}$$

$$\mathrm{d}U_{\text{quality},i}\left(t\right) = \eta\int_t^\infty \log\left(\frac{\text{quality}_i\left(s\right)}{\text{quality}_{row}\left(s\right)}\right)\mathrm{e}^{-\rho(s-t)}\mathrm{d}s \tag{16c}$$

The quotient in (16a) captures the relative wealth of a potential migrant between i and *row*. As discussed above, migration implies a change only in labor wealth with asset wealth remaining the same.

Henceforth I will assume that the local quality of life is time invariant. Such an assumption obviously does not allow for congestion effects or for provision of quality of life through some public choice mechanism and so reemphasizes that quality of life should be thought of as exogenously determined — e.g., the weather, or proximity to lakes, the ocean, mountains, et cetera.

2.6 Dynamics

The dynamic system can now be expressed as a system of seven differential equations in $\{L_i(t),\, \widehat{k}_i(t),\, \widehat{\text{assets}}_i(t),\, q_{K,i}(t),\, dU_{\text{wealth},i}(t),\, dU_{\text{price},i}(t),\, \widehat{\text{value}}_i(t)\}$.[6] The first three of these, $\{L_i(t),\, \widehat{k}_i(t)$, and $\widehat{\text{assets}}_i(t)\}$, — are "state" variables which are instantaneously fixed (i.e., they can not "jump"). The remaining four, $\{q_{K,i}(t),\, dU_{\text{wealth},i}(t),\, dU_{\text{price},i}(t)$, and $\widehat{\text{value}}_i(t)\}$, are "co-state" variables which can jump, but only in reaction to unexpected system shocks. The dynamic system is mutually recursive with respect to all of the variables with the

[6] "Hatted" variables denote the normalization by e^{xt} so that the transformed variables remain constant in a steady state. See (12).

exception of $\widehat{\text{value}}_i(t)$; none of the remaining system variables depends on the evolution of $\widehat{\text{value}}_i(t)$ and so it could be dropped from the system without further loss of information; I retain $\widehat{\text{value}}_i(t)$ because it maps to a key local observable. The actual expressions for the differential equations are deferred until Appendix A.

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

2.7 Local Steady State and "Comparative Statics"

The local steady state can be derived by setting each of the seven system differential equations just discussed, (A.1a) – (A.1g), equal to zero and solving for the state and co-state variables. The actual expressions are again deferred until Appendix A. The steady-state values of two of these, $\{\widehat{k}_i(t),\ q_{K,i}(t)\}$, are determinate in that they can be expressed as a function of exogenous parameters alone. The remaining five system variables, $\{L_i(t)$, $\widehat{\text{assets}}_i(t)$, $dU_{\text{wealth},i}(t)$, $dU_{\text{price},i}(t)$, and $\widehat{\text{value}}_i(t)\}$, collectively have one degree of freedom in the sense that in addition to the exogenous parameters, the steady-state value of one of these needs to be known to determine the steady-state values of the other four.

The "extra" degree of freedom results from the fact that the overall system is subject to history dependence. For the intuition on how this arises, consider two localities, i and j, identical in all exogenous parameters, but having a different history of local development. In particular, at some point in the distant past i experienced a "helicopter drop" of installed physical capital. At this same point in the distant past, j experienced an "artillery drop" which destroyed a large portion of its installed capital base. (Thankfully, no one was injured.) The steady-state levels of labor income will be identical between the two localities. But during the transitions to their respective steady states, i's residents have high current relative to permanent income whereas j's residents have low current relative to permanent income.

Consumption smoothing leads i's residents to accumulate but j's residents to decumulate asset wealth during the transition to the steady state. It immediately follows that in these steady states, i's residents have a higher asset wealth than j's residents. While the steady-state price of housing services will be identical between the two localities — if not, there would be an incentive to migrate — the higher asset wealth of i's residents means that they will be purchasing a higher steady-state *quantity* of housing services. With equal aggregate flows of housing services, this can only be if the population of i is smaller than that of j.

The story illustrates that the one degree of freedom with respect to the system variables in no way implies that there is any possibility of "choice" over steady states (other than altering the exogenous parameters). On the contrary, the system is fully determined; it is just that this determination is based both on the "static" exogenous parameters as well as the history of local shocks. Individuals' consumption smoothing serves as the underlying mechanism.[7]

But the story also illustrates that the nature of the history dependence is somewhat perverse: a "good" but temporary shock causes an economy's steady-state population to fall whereas a "bad" but temporary shock causes an economy's steady-state population to rise. Here, the key underlying mechanism is the assumed inelastic supply of housing services. With local size as measured by housing stock fixed, local size as measured by population depends primarily on local income distribution. And local income distribution, in turn, depends primarily on modeling assumptions for which there is no obvious choice (e.g., the asset wealth of migrants, integer constraints on housing quantity consumption, the possibility of bidirectional gross labor flows). That the *nature* of the hysteresis depends closely on assumptions suggests attaching little importance to it. But such fragility does not extend to the *existence* of the hysteresis, a result which is robust across a wide range of assumptions (Rappaport 2000a).

Comparative steady-state "statics" can now be calculated for various local observables. Table 5 contains a summary and Appendix A includes a more detailed discussion.

2.8 Long Run Population Flows

The local growth steady state described above is characterized by the constancy of each of the system variables when normalized by the rate of technological progress. A strong assumption underlying this constancy is that housing services flow at a fixed rate. More realistically, there is likely to be at least some elasticity in housing-service supply. If so, local growth theory suggests that technological progress should induce a long run population flow from high productivity to high quality of life locales. Here, "long run" is meant to connote

[7] So one way to remove such hysteresis would be to allow individuals to insure against geographically-based shocks.

Table 5

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

	L_i^*, $\widehat{\text{value}}_i^*$	$\widehat{k}_i^*$, $\widehat{w}_i^*$	$q_{K,i}^*$
A_i	+	+	0
quality_i	+	0	0
$b_{K,i}$	−	−	+
$b_{L,i}$	0	0	0

Note: Comparative statics for L_i^* and $\widehat{\text{value}}_i^*$ hold constant the endogenous steady-state level of $assets_i^*$.

a timeframe an order of magnitude larger than is relevant for transitional dynamics.[8]

With positive technological progress in production of the tradable good, $x > 0$, per capita tradable consumption is rising and so the marginal utility of tradable consumption is falling with time. Individuals, therefore, should be increasingly willing to substitute lower tradable consumption for higher housing-service consumption and for higher quality of life. The model's fixed supply of housing services along with the assumption that the elasticity of intertemporal substitution is the same for housing services as it is for quality of life together imply that the local steady-state price of housing services rises at exactly the right rate to offset the increasing marginal utility of both housing services and quality of life relative to output consumption. The utility value of local quality of life is thus fully capitalized into local steady-state housing service prices.

If, however, the quantity of housing services supplied responded to changes in the price of housing services (or if the elasticity of intertemporal substitution were greater for housing services than for quality of life) housing service prices which rose at the rate of exogenous technological progress would no longer be sufficient to offset increasing demand for local

[8]Formally, for any arbitrarily chosen time τ, it is generally possible to choose an $\epsilon > 0$ such that the transitional time for a state variable to differ from its steady-state value by less than ϵ will exceed τ. In the present case, uniquely distinguishing long run dynamics is that starting from an instantaneous equilibrium where individuals and firms realize equal utility and profit *flows* across all localities and *absent* any shock, that nevertheless the system will be characterized by net population flows. Whether a normalization exists which allows each of the system variables to be expressed in constant (i.e., a "steady state") form is an open question.

quality of life. Rather, a permanent utility gradient would exist between low and high quality-of-life locales so that population would flow from the former to the latter.

3 Transitional Dynamics Following Local Shocks

Numerical methods readily sketch out the impulse response to three different types of shocks: to a single locality's productivity, to a single locality's quality of life, and to a single locality's capital stock.[9] These highlight both the persistent population flows resulting from small capital and labor frictions as well as that wages and house sales prices tend to remain relatively close to their steady-state levels along transition paths.

The capital and labor fractions are henceforth assumed to be equal across localities. To give meaning to the idea that they are "small", the associated parameters b_K and b_L are mapped to more intuitive measures. From (11) and (A.2d), for given rates of depreciation and exogenous technological progress, the capital friction maps one-to-one with the steady-state shadow value of capital, q_K^*. Similarly, for a given rate of time preference, the labor friction maps one-to-one with the relative wealth necessary to induce a one percent annual rate of net migration, ω; from (14) and (16a), $\omega = \exp(0.01 \cdot \rho \cdot b_L)$.

Aggregate empirical timeseries suggest that the shadow value of capital tends to remain relatively close to one (Summers, 1981; Blanchard, Rhee, and Summers, 1993). However, more recent research by Barnett and Sakellaris (1998) using panel data on firms over the period 1960 to 1987 finds a median average value of installed capital $q_K = 1.23$ which rises to $q_K = 1.79$ after adjusting for investment tax incentives. Calibrations of the Ramsey model generally choose a steady-state shadow value of capital at or above this latter range in order to slow down implausibly fast speeds of income convergence.[10] Herein, $q_K = 1.56$ is chosen as a base calibration but all results are robust to substantially higher levels of capital mobility (i.e. lower values of q_K^*).

Benchmarking the labor mobility parameter requires measuring the responsiveness of net migration to differences in total real wealth while controlling for quality of life. Proxying

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[9] In all three cases, the rest-of-world integrated macroeconomy is assumed to remain in its steady state. The qualitative results presented here and are expected to remain unchanged to relaxing this assumption. See footnote 17 below.

[10] Rappaport (2000b) shows that introducing an aggregate average installation cost which is convex increasing with respect to gross investment allows the Ramsey model to be calibrated to achieve both a steady-state shadow value of capital very close to one as well as a slow speed of convergence.

for total real wealth with current wages along with the difficulty in controlling for quality of life together introduce a considerable downward bias to estimates of labor mobility. For instance Barro and Sala-i-Martin (1991, 1995) examine the relationship between net migration and initial wage levels for U.S. states for each decade, 1900 through 1990; their *highest* estimate of labor mobility suggests that a 25 percent nominal wage differential is necessary to induce a 1 percent rate of net migration. That it takes such a large real wealth premium to induce a 1 percent rate of net migration within an integrated macroeconomy (such as the United States in the late 20th century) does not seem plausible. (For a more detailed discussion, see Rappaport, 2000a.)

An alternative approach to measuring the degree of labor mobility proposed by Gallin (1999) focuses on the migration response to differences in current wages while controlling for differences in future labor wealth by including expected future migration. The coefficient on current wages can be interpreted as the migration response to the implied difference in labor wealth; in other words, it is straightforward to calculate the ratio of local to *row* labor wealth implied by a given ratio of local to *row* wages which lasts for one period only. Depending on the assumed real interest rate, Gallin's baseline estimate implies that it takes from a 0.3 percent to a 1.0 percent labor wealth premium to induce a 1 percent rate of net migration. Actual labor mobility may be even higher as Gallin does not control for variations in quality of life.[11]

Consistent with Gallin's estimates, the present paper assumes a "base" level of labor mobility such that a 1 percent real wealth differential is sufficient to induce a 1 percent annual rate of net migration ($\omega = 1.01$). As discussed below, all results are robust to substantial variations in the level of labor mobility both above and below this base level.

Following a shock to local total factor productivity which causes steady-state local wages to rise by five percent, under the base calibration population requires 54 years to close 95 percent of the distance to its new steady state. Following a shock to local quality of life such that individuals would be willing to pay five percent more for housing services while still attaining their reservation level of utility, under the base calibration population

[11]Including expected future migration should be able to control for future differences in quality of life. But in the present case, Gallin proxies for expected migration using actual future migration instrumented only by predicted employment growth based on industry shares. To the extent that such an instrument fails to capture quality-of-life attributes, expected migration will be that arising from productivity-based wealth differences only.

requires 49 years to close 95 percent of the distance to its new steady state. This high persistence derives from labor and capital's complementarity in production. Even with perfect labor mobility, not everyone who will eventually migrate to the locality does so immediately; rather individuals continue to flow into the locality as capital flows in.

The remainder of this section focuses in more detail on the dynamics following productivity and quality-of-life shocks under both the base and alternative calibrations. For completeness and to facilitate the next section's empirical analysis, a third subsection briefly sketches the dynamics following a shock to local capital stock. Finally, a last subsection briefly discusses the plausibility of the compensating differential literature's identifying assumption that wages and house prices are near their steady state levels.

3.1 Local Productivity Shock

A local productivity shock is meant to connote any set of circumstances which interact with a locality's fixed attributes to cause a change in long-run productive potential. In the early 19th-century, navigable rivers served as a major source of commercial transportation within the continental United States; over the course of the late-19th and 20th centuries, railways and then trucking have largely replaced river-borne commerce. And so in the early 19th-century, location near a navigable river bestowed a considerable productivity advantage to local producers of tradable goods; at some later point, this productivity advantage eroded. More recently, the North American Free Trade Agreement would seem to have increased the productive potential of localities on the U.S.-Mexico border. Note that here and below, the integrated macroeconomy (i.e., excluding locality i) is assumed to remain in its steady state. Relaxing this assumption to allow for a transition among several large localities is expected to reinforce the single-locality dynamics. (See footnote 17 below.)

Figure 1 shows the impulse response following a positive productivity shock which causes a locality's steady-state wage level to increase by 5 percent. For an economy with a 30 percent ("narrow") capital share, $\alpha = 0.30$, such a shock is equivalent to a 3.5 percent increase in total factor productivity.[12] The depreciation rate, rate of time preference, and

[12] The narrow capital share parameterization 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 (1991) and Barro and Sala-i-Martin (1995) to argue for a broad capital share, for instance $\alpha = 0.75$, corresponding to a more metaphorical interpretation of capital to include

rate of technological progress — enumerated on the right hand side of the figure — are the same as in Barro and Sala-i-Martin (1995). The housing share of consumption is set at 40 percent ($\zeta = 0.40$), which is much higher than the actual 15 percent of U.S. personal consumption expenditures imputed to narrowly defined housing services, in order to capture nontradable goods more generally (e.g., locally-provided services including the portion of tradable-good retail prices attributable to local wages and land prices). The effect of varying the housing share will be discussed below.

Local wages and hence local labor wealth jump discretely with the positive productivity shock at time zero (Panel B) inducing an inflow of population (Panel A). Similarly, the shadow value of capital (not shown) jumps discretely at time zero inducing a gross capital inflow. The two flows reinforce each other resulting in an extremely long transition. Population takes 25 years to close 75 percent of the distance to its new steady state level and 54 years to close 95 percent of this distance. Twenty-five years after the shock, the annual rate of in-migration remains at 0.10 percent or — alternatively — 0.25 its initial post-shock value. Hereafter, I use the time it takes a variable to close 95 percent of the distance from its pre-shock to new steady-state level as a first measure of persistence and one plus the (negative) growth rate of net migration over the 25 years following the shock as a second measure of persistence; the latter is exactly the continuous time analog of an annual discrete autoregressive coefficient. For the base calibration, net migration's autoregressive persistence so measured equals 0.945.

House rental prices jump discretely at time zero (Panel C), a result of the discrete jump in local labor wealth; thereafter they continue to rise, driven both by the continued rise in labor wealth and by the population inflow. House sales prices jump even more sharply at time zero, a result both of the jump in local labor wealth as well as the future population inflow. The rising house prices lower utility flows to local residents eventually eliminating the premium driving net migration.

The infinite growth rates associated with the jumps at time zero imply that wages and house prices will show low autoregressive persistence. That is, to someone observing a discrete timeseries beginning at time zero, the growth rates for wages and house prices will

human capital. For the purposes of local growth theory, however, interpreting broad capital to include human capital is especially problematic given that short-term constraints on human capital formation may be better captured by the labor rather than the capital frictions (i.e., human capital can "move"). Even so, Tables 6 and 7, below, consider the case of a moderately broad capital share, $\alpha = 0.60$.

be extremely high during the first subperiod but much lower during subsequent subperiods. Even allowing that a real world "shock" may span several subperiods, initial high rates of growth for wages and house prices will be followed by much lower ones. Similarly, the discrete jumps by house sales and rental prices account for population's flowing toward high house prices.

Under most calibrations, the labor inflow is dominated by the gross capital inflow everywhere along the transition path so that wages are always rising. But when labor mobility is very high relative to capital mobility, labor may initially flow in at a faster rate than does gross capital. Such is the case in the "high labor mobility" calibration of Figure 2. Here, the wealth premium needed to induce a one percent rate of net migration is just one-eighth of a percentage point, $\omega = 1.00125$ (i.e., the labor friction is just one-eighth its level under the base calibration); all other parameters are the same as in Figure 1. Immediately following the positive productivity shock, labor flows in at a 0.92 percent rate whereas capital flows in at only a 0.78 percent rate: hence wages are initially falling (following their jump upward).

Figure 2 also shows a "low labor mobility" calibration in which the wealth premium needed to induce a one percent rate of net migration is eight percentage points, $\omega = 1.08$, or eight times its level under the base calibration. Even though the level of *capital* mobility remains the same under both the high- and low-labor-mobility calibrations, notice in Panel B that the faster high-labor-mobility population inflow induces a faster gross capital inflow.

Net migration's high persistence following a productivity shock proves extremely robust. Table 6 shows summary results for various combinations of capital and labor mobility under both a narrow and broad capital share. For a given capital share, each of the panels represents a tripling of capital mobility compared to the panel above; within each panel, each line represents a doubling of labor mobility compared to the line above. Autoregressive persistence measured over the 25 years following the shock (column 14) is higher the lower is capital mobility, the lower is labor mobility, and the broader the capital share.[13] Even the "least persistent" listed calibration (Table 6 Panel C, last line: $q_K^* = 1.14$, $\omega = 1.000625$, $\alpha = 0.30$) is characterized by a moderately high 0.846 autoregressive persistence and re-

[13] Note that the broad capital share calibration requires just a 2.0 percent increase in productivity to effect a five percent rise in steady-state wages versus the 3.5 percent rise in productivity required under the narrow capital share calibration.

quires 22 years for population to close 95 percent of the distance to its new steady state.

Of course, reducing *both* the labor mobility and capital mobility frictions should allow persistence to be made arbitrarily small; in the limiting case of a completely frictionless system, all variables will immediately jump to their new steady-state levels. 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 will be flowing in over time, the other "wants" to do so as well (see Appendix B).[14]

Net migration's high persistence is similarly robust to changes in the housing share of consumption. A larger housing consumption share both lowers the utility benefits of higher tradable-denominated wages and increases the utility costs of higher housing prices. Consequently, as the housing consumption share rises, the increase in steady-state population and the time for population to close 95 percent of the distance to this new steady state fall. Even so, with a 60 percent housing share along with the remainder of the base calibration, it still takes population 47 years to complete 95 percent of the transition brought about by just a 3.5 percent rise in total factor productivity. The autoregressive measure of persistence remains relatively constant, regardless of housing consumption share.

3.2 Local Quality-of-Life Shock

A local quality-of-life shock is meant to connote any set of circumstances which interact with a locality's fixed attributes to make the locality an inherently more or less pleasurable place to live. The most obvious example is the impact of air conditioning on previously uninhabitable desert localities; the growth of new leisure activities such as surfing and skiing serves as a second example.

Figure 3 summarizes the dynamics following an increase in quality of life such that

[14] To be sure, the frictionless of the two will also jump discretely concurrent with the shock. For the case of perfect labor mobility but imperfect capital mobility, Appendix B proves that along transition paths, utility *flows* will differ between a locality and the remaining rest-of-world integrated macroeconomy (by definition, the utility *levels* must be equal). Following a positive productivity shock, the most likely scenario would be a discrete jump in local population followed by gross population inflows slightly exceeding gross population outflows as gross capital transitions to its new steady state. During an individual's "rotation" into the locality, she realizes a utility flow below the rest-of-world level (due to lower housing service consumption) but accumulates assets (due to higher wages) which are used to raise future utility flows upon return to the remaining rest-of-world integrated macroeconomy.

local individuals are willing to pay a five percent premium for housing services while still attaining their reservation utility. So defined, the *absolute* size of the quality-of-life shock is directly proportional to the housing consumption share, ζ, and inversely proportional to the quality-of-life weighting parameter, η (see (A.2g)). For an intuitive sense of whether such an increase in quality of life is "small", consider that across the 50 largest U.S. cities in 1990, the median rent for a two-bedroom apartment ranged from $373 in Cleveland to $877 in San Francisco. To the extent that such price variations reflect underlying differences in quality of life, the five percent premium is 1/27th the San Francisco-Cleveland difference. Of course, observed price variations also reflect productivity differences as well as heterogeneous workforce and housing stock characteristics between places. And so alternatively, empirical work by Bloomquist et al. (1988) and Gyourko and Tracy (1991) implies that a five percent housing premium compensates for an increase in sunshine by 6 to 8 percentage points (of percent of time possible; the mean across U.S. metropolitan areas is 61 percent). Or rule-of-thumb pricing suggests that a five percent premium compensates for a ten floor rise between otherwise identical New York City rental apartments.[15]

The positive shock to quality of life at time zero induces a population inflow (Panel A) in turn putting downward pressure on wages (Panel B — but note the very small magnitude of the vertical scale). Because both productivity and gross capital stock are instantaneously fixed, wages do not jump discretely concurrent with the shock. The sales price of housing services, however, does discretely jump upward due to the positive impact from the future population inflow overwhelming the negative impact from the jump downward in labor wealth (Panel C). The jump downward in labor wealth, in fact, also causes the rental price of housing services to jump downward, though by a magnitude too small to be visible in the figure. The population inflow puts upward pressure on the house rental prices which in turn dampens the incentive for in migration. The population inflow also elicits an inflow of gross capital; eleven years after the shock the rate of gross capital inflow comes to exceed that of population so that wages begin rising back towards their original level.

[15]The city rental prices are derived from 1990 decennial census data. For New York City rental apartments, the rule-of-thumb is that a one floor rise raises prices by 1/2 a percentage point, more when there is a significant change in view (author correspondence with Charles Singer and Nancy Packes, Rockrose Development Corporation Director of Market Research and independent real estate consultant, respectively). Unit pricing data from several New York City luxury condominium developments suggest that the price rise per floor may be as much as 2 percentage points.

The complementarity of labor and capital in production again effects an extremely long transition. Population takes 21 years to close 75 percent of the distance to its new steady state level and 49 years to close 95 percent of this distance. Autoregressive persistence over the 25 years following the shock equals 0.926. The high persistence of population flows following a quality-of-life shock is fairly robust. Under the high labor mobility calibration shown in Figure 4 (i.e., tripling labor mobility from the base calibration such that just one-eighth of a percentage point wealth premium induces a one percent rate of net migration), population still requires 32 years to close 95 percent of the distance to its new steady state; autoregressive persistence remains at 0.855. For the combination of very high labor mobility along with very high capital mobility (Table 7 Panel C, last line: $q_K^* = 1.14$, $\omega = 1.000625$, $\alpha = 0.30$), the corresponding persistence measures are 18 years and 0.807 (Table 7 Panel C, last line).

House sales prices, in contrast, show very little persistence, a result of their initial discrete jump. And wages show negative autoregressive persistence, though this latter result is especially sensitive to time period (i.e., for someone who observes only part of the transition path).

As with a productivity shock, population flows toward high house prices. In particular note the positive correlation between net migration and initial house *rental* price starting shortly following the quality-of-life shock (Figure 3 Panels A and C); this shows that an initial discrete jump is *not* a necessary condition for population to flow toward high house prices.

3.3 Local Capital Shock

A "negative capital shock" is meant to connote any set of circumstances which leaves a locality with a low installed capital base relative both to the remainder of an integrated macroeconomy and to its own steady-state level. Literally interpreted, negative capital shocks might correspond to natural and man-made disasters. More metaphorically, negative capital shocks might correspond to changes in technology or the terms of trade which disproportionately affect the installed capital base of some localities relative to others but which do not fundamentally alter long run relative productivity: for instance, changes in manufacturing techniques in steel production on certain areas of the Midwest United States during the early 1980s.

Figure 5 summarizes the dynamics following a shock to a locality's capital stock which leaves wages at 60 percent of their steady-state level. All underlying local parameters are the same as in the remaining integrated macroeconomy. Immediately following the shock, population begins to rapidly flow out of the locality (Panel A). The decrease in local wages causes both the sales and rental price of land to jump downward; the rental price of land then continues to fall driven by the outflow of population (Panel C). Again population flows towards high house prices (i.e., away from low local house prices). Not shown is the large inflow of gross capital stock that the negative capital shock induces.

The population outflow and the capital inflow both tend to increase wages; higher wages along with lower house prices eventually reverse the population outflow (so now population flows toward low house prices). As population flows back into the locality, gross capital formation remains sufficiently positive to allow wages to continue to converge back towards their steady-state level. House sales and rental prices also gradually return to their steady-state levels.

That the new study-state population density exceeds its preshock level crisply shows the history dependence discussed in the theory section above. As emphasized there, the specific nature of the history dependence is especially sensitive to assumptions (e.g., the inelasticity of housing supply, the asset wealth of migrants). But the result that each locality's steady-state population depends not just on current exogenous characteristics, including productivity and quality of life, but also on the historical timeseries of local development is completely general.

The complementarity of capital and labor in production leads each to reinforce the other in speeding transitions following productivity and quality-of-life shocks. But following a capital shock, the complementarity can be offsetting. Intuitively, higher labor mobility increases the speed at which per capita income converges to its steady state level as the more rapid outmigration raises capital intensity. But the more rapid outmigration also lowers the incentive for gross capital formation. These two effects roughly offset each other so that the speed of income convergence proves relatively insensitive to the degree of labor mobility (Rappaport, 2000a).

Within the neoclassical local growth framework developed herein, a capital shock completes the possible sources of local growth dynamics.

3.4 Biases in Estimating Productivity and Quality of Life

The key identifying assumption underlying the compensating wage and house price differential literature (Rosen, 1979; Roback, 1982; Blomquist et. al., 1988; Gyourko and Tracy, 1989, 1991) is that local wages and local house prices are at their steady-state levels and thus fully reflect underlying productivity and quality of life. But high, persistent population flows over the period 1971 to 1988 lead Greenwood et al. (1991) to conclude that the integrated macroeconomy made up of the U.S. states is away from its long-run steady-state level thereby biasing compensating differential estimates of local productivity and quality of life. Gyourko, Tracy, and Kahn (1999) strongly agree that empirical strategies which allow the relaxing of the steady-state assumption stand out as among the most important challenges facing this literature.

The numerical results above suggest that any biases to estimates of compensating differentials due to transitional dynamics may be significantly smaller than suggested by net population flows. This conclusion follows from the much quicker movement by wages and house sales prices towards their steady-state levels compared to the extended transition by population.

Concurrent with the 3.5% productivity shock, wages and house sales prices jump 70% and 83% of the distance to their new steady states under the base calibration (Figure 1 and Table 6 Panel B). Population, in contrast, is fixed instantaneously; Twenty-five years after the shock, wages and house sales prices have closed 93% and 96% of the distance to their new steady states, but the annual rate of population inflow remains at 0.10%. Concurrent with the quality-of-life shock, house sales prices immediately jump to close 76% of their assumed 5 percentage point steady-state rise (both current and steady-state wages remain unchanged) (Figure 3 and Table 7 Panel B). Twenty-five years after the shock, house sales prices have closed 95% of the distance to their new steady state but the annual rate of population inflow remains at 0.06%.

The dichotomy between the slow speed at which population moves toward its steady state and the rapid speeds at which wages and house prices do so is a moderately robust result. It depends critically on a capital share which is not "too broad"; but as argued in footnote 12 above, the human capital interpretation underlying a broad capital share suggests that for local growth theory, parameterizing the friction to capital mobility with a narrow capital share is more appropriate. Decreasing the level of labor mobility and lowering the housing consumption share also tend to slow the speed at which house sales prices move toward their steady-state levels.

Together these numerical results suggest that persistent population flows notwithstanding, estimating compensating differentials based on the assumption that wages and house sales prices are close to their steady states does not seem unreasonable. Of course, numerous caveats pertain. These include that real world "jumps" by wages and house sales prices are unlikely to be perfectly discrete and hence wages and house prices may remain far from their steady states for a few years immediately following productivity and quality-of-life shocks. Moreover the possibility of local capital shocks complicate matters as these similarly cause wages and house prices to deviate substantially from their steady states.[16]

4 U.S. State and County Growth

So what are the sources driving the persistent population flows? The theoretical results above help to interpret some summary empirics on growth across U.S. counties during the 20th-century. The empirics suggest that circa 1930, the United States experienced a shock which realigned productivity across its localities and which has been driving population flows ever since; that circa 1960, quality-of-life considerations became more important in driving population flows; and that circa 1970, a large number of U.S. localities experienced something akin to a capital shock. These interpretations are meant as a broad first pass at the data; doubtless, the summary empirics may be consistent with other interpretations.[17]

[16]Note that at the the population extremum following a capital shock, wages and house prices deviate substantially from their steady states despite zero net population flows.

[17]An additional caveat: the dynamic responses sketched above assume a shock to a single locality within an integrated macroeconomy otherwise at its steady state. Shocks to a group of localities which collectively are no longer small should induce qualitatively similar "mirror" dynamics in the remaining macroeconomy. For example, suppose all California localities experience a negative productivity shock (for instance due to more stringent anti-pollution standards). As these localities account for a significant portion of the U.S. population (12 percent in 1990), it is as if the remaining U.S. localities experienced an increase in their relative productivity, and so the outflow of population from the California localities would be mirrored by inflows of population spread across the rest of the country. Presumably housing value and per capita income dynamics would similarly mirror those in California. However additional assumptions, such as an asymmetrical response of housing stock to positive versus negative demand shocks, might make the integrated system's dynamics somewhat more complicated than those of a single locality. Future theoretical research needs to address such possibilities.

Table 1 Panel A shows that the persistence of state population growth rates increased markedly from the 1930s to the 1950s; regressing decennial population growth rates on their lagged value and a constant accounts for no more than 24 percent of the variation in state growth rates for the 1910s through the 1930s rising to 46 percent for the 1940s rising to 70 percent for the 1960s. For U.S. counties, the persistence of population growth rates begins only around 1930 (Table 1 Panels A and B). The same regression accounts for no more than 3 percent of the variation in county growth rates for the 1910s through the 1930s rising to 12 percent for the 1940s rising to 46 percent for the 1950s. This large increase in the persistence of net population flows at both the state and county level suggests a permanent shock, either to productivity or to quality of life. That 1929 marks the start of the Great Depression followed in a few years by the ratcheting up of the size of the U.S. federal government under New Deal legislation points to productivity as the more likely shock.

The persistence of county net migration closely mirrors that of population growth, especially from the 1960s forward (Table 1 Panel C). County employment growth also shows considerable, if slightly lower, persistence with the notable exception of the 1960s (Table 1 Panel D).

Several unique characteristics distinguish county growth rates during the 1960s. County employment growth during the 1960s shows moderate serial correlation with employment growth during the 1950s but much lower serial correlation with employment growth during the 1970s and 1980s. County net migration during the 1960s, in contrast, retains its "typical" high serial correlation with both previous and subsequent net migration. As a consequence, net migration and employment growth show a much lower cross correlation during the 1960s than during other decades (Table 3 Panel B). Also unique to the 1960s is the negative correlation between per capita income growth and each of net migration and employment growth. These latter negative correlations along with the persistence of net migration are together consistent with an increase in the importance of quality-of-life considerations in driving population flows; for instance, increasing suburbanization facilitated by the recently funded interstate highway system, or increasing movement to southwest "sunbelt" locations facilitated by the spread of inexpensive air-conditioning technology. Reconciling such an explanation with the moderate backward but low forward persistence of employment flows relies on employers' eventually — but not immediately — following the population flows to the high quality-of-life localities.

A different set of unique characteristics distinguish county growth rates during the 1970s. Population growth rates from the 1940s and later are less highly correlated with population growth during the 1970s than with population growth during the 1980s (Table 1 Panels B, C, and D, last two rows). The growth rates of median house values, per capita income, and median family income each show negative serial correlation between the 1970s and 1980s (Table 2). Consistent with these correlations is that circa 1970, the United States experienced something akin to a capital shock which *temporarily* impacted income and employment opportunities across its localities; for instance, the sharp increase in oil prices accompanying the 1973 OPEC embargo and subsequent industrial restructuring. The initial rapid population outflow from negatively impacted localities would thus partly mask longer-term productivity and quality-of-life driven population flows; the negative serial correlations capture the eventual movement by house prices and income back towards their original levels (i.e., Figure 5, Panels B and C). The lack of empirical evidence of a reversal in population flow is not especially troubling given the predicted gradual nature of the reversed below, the ongoing dynamics from the hypothesized earlier shocks, and the need for more recent data.

Of course, these summary empirics are likely to be consistent with other interpretations. Multiple types of local shocks; the associated overlapping dynamics from extended transitions; and the non-observability of steady-state population, wages, and house prices makes formal hypothesis testing of the model laid out herein extremely difficult. Instead the hope is that a local growth framework built up from optimizing agents and the interpretations which it suggests can serve as a *starting* point for understanding local dynamics.

5 Conclusions

Extending the Ramsey-Cass-Koopmans growth model to allow for mobile labor shows that small frictions to both labor and capital mobility along with small changes in either productivity or quality of life together suffice to effect highly persistent population flows. Wages and house prices, in contrast, approach their steady-state levels relatively quickly because they are able to “jump” concurrent with the changes to productivity and to quality of life. Such jumps can account both for the observed low serial correlations of per capita income growth and house price growth as well as for the observed population flow toward high house prices. The much more rapid movement by house prices and wages relative to population implies that persistent population flows do not necessarily contradict the compensating differential literature's identifying assumption that wages and house prices are near their long run steady states.

Highly persistent population flows across U.S. states and counties suggest that some time around 1930, the United States experienced a shock which realigned productivity across its localities and which in large part has driven population flows ever since. In addition, the data suggest that some time around 1960, quality of life considerations became important in driving population flows and further that a capital shock temporarily drove population flows during the 1970s.

These results suggest a wide-ranging research agenda. On the theoretical side, endogenizing local housing supply is a top priority. Doing so should obviate the need for a separately specified labor mobility friction and allow for a more plausible modeling of local history dependence. On the empirical side, more detailed analysis is needed to test the existence and explore the nature of the hypothesized productivity, quality-of-life, and capital shocks. As the exogenous correlates of population flows will also be the exogenous correlates of the driving shocks themselves, identifying these correlates can help us understand the changing determinants of productivity and quality of life.

Appendices

A Local Growth Equations of the Motion and Steady-State Levels

The system equations of motion are given by,

$$\frac{\mathrm{d}}{\mathrm{d}t} L_i = \frac{dU_{\text{wealth},i} + dU_{\text{price},i} + dU_{\text{quality},i}}{b_{L,i}} L_i \tag{A.1a}$$

$$\frac{\mathrm{d}}{\mathrm{d}t} \hat{k}_i = \left(\frac{q_{k,i} - 1}{b_{k,i}} - \delta - x - \frac{dU_{\text{wealth},i} + dU_{\text{price},i} + dU_{\text{quality},i}}{b_{L,i}} \right) \hat{k}_i \tag{A.1b}$$

$$\frac{\mathrm{d}}{\mathrm{d}t} \widehat{\text{assets}}_i = (1-\alpha) A_i \hat{k}_i^a + \rho \, \widehat{\text{assets}}_i - \rho \left(\widehat{\text{labor\_wealth}}_{row} + \widehat{\text{assets}}_i \right) \mathrm{e}^{\rho \, dU_{\text{wealth},i}} \tag{A.1c}$$

$$\frac{\mathrm{d}}{\mathrm{d}t} q_i = (\delta + \rho + x) \, q_{K,i} - \alpha A_i \hat{k}_i^{-(1-\alpha)} - \frac{(q_{K,i} - 1)^2}{2 b_{k,i}} \tag{A.1d}$$

$$\frac{\mathrm{d}}{\mathrm{d}t} dU_{\text{wealth},i} = \mathrm{e}^{\rho dU_{\text{wealth},i}} - \frac{(1-\alpha) A_i \hat{k}_i^a + \rho \widehat{\text{assets}}_i}{\rho \left(\widehat{\text{labor\_wealth}}_{row} + \widehat{\text{assets}}_i \right)} \tag{A.1e}$$

$$\frac{\mathrm{d}}{\mathrm{d}t} dU_{\text{price},i} = \zeta \log \left(\frac{\zeta \rho \left(\widehat{\text{labor\_wealth}}_{row} + \widehat{\text{assets}}_i \right) L_i}{\hat{p}_{row} N_i} \right) \tag{A.1f}$$

$$\frac{\mathrm{d}}{\mathrm{d}t} \widehat{\text{value}}_i = \rho \, \widehat{\text{value}}_i - \frac{\zeta \rho \left(\widehat{\text{labor\_wealth}}_{row} + \widehat{\text{assets}}_i \right) L_i \, \mathrm{e}^{\rho dU_{\text{wealth},i}}}{N_i} \tag{A.1g}$$

Setting each of the system equations equal to zero implies steady-state levels,

$$L_i^* = \left(\frac{(1-\alpha)(A_i)^{\frac{1}{1-\alpha}} \left(\frac{2\alpha}{\widetilde{b}_{K,i}} \right)^{\frac{\alpha}{1-\alpha}} + \rho \cdot \widehat{\text{assets}}_i^*}{(1-\alpha)(A_{row})^{\frac{1}{1-\alpha}} \left(\frac{2\alpha}{\widetilde{b}_{K,row}} \right)^{\frac{\alpha}{1-\alpha}} + \rho \cdot \widehat{\text{assets}}_i^*} \right)^{\frac{1}{\zeta}} \cdot \left(\frac{\text{quality}_i}{\text{quality}_{row}} \right)^{\frac{\eta}{\zeta}} \cdot \left(\frac{(1-\alpha)(A_{row})^{\frac{1}{1-\alpha}} \left(\frac{2\alpha}{\widetilde{b}_{K,row}} \right)^{\frac{\alpha}{1-\alpha}} + \rho \cdot \widehat{\text{assets}}_{row}^*}{(1-\alpha)(A_i)^{\frac{1}{1-\alpha}} \left(\frac{2\alpha}{\widetilde{b}_{K,i}} \right)^{\frac{\alpha}{1-\alpha}} + \rho \cdot \widehat{\text{assets}}_i^*} \right) \cdot \left(\frac{N_i}{n_{row}} \right) \tag{A.2a}$$

$$\widehat{k}_i^* = (A_i)^{\frac{1}{1-\alpha}} \left(\frac{2\,\alpha}{\widetilde{b}_{K,i}} \right)^{\frac{1}{1-\alpha}} \tag{A.2b}$$

where,

$$\widetilde{b}_{K,i} \equiv 2(x + \rho + \delta) + (x^2 + \delta^2 + 2x\delta + 2x\rho + 2\delta\rho) \cdot b_{K,i}$$

$$\widehat{\text{assets}}_i^* = \widehat{\text{assets}}_i^* \tag{A.2c}$$

$$q_{K,i}^* = 1 + (x+\delta)\, b_{K,i} \tag{A.2d}$$

$$dU_{\text{wealth},i}^* = \frac{1}{\rho}\log\left(\frac{(1-\alpha)\,(A_i)^{\frac{1}{1-\alpha}}\left(\frac{2\alpha}{\widetilde{b}_{K,i}}\right)^{\frac{\alpha}{1-\alpha}} + \rho\cdot\widehat{\text{assets}}_i^*}{(1-\alpha)\,(A_{row})^{\frac{1}{1-\alpha}}\left(\frac{2\alpha}{\widetilde{b}_{K,row}}\right)^{\frac{\alpha}{1-\alpha}} + \rho\cdot\widehat{\text{assets}}_i^*}\right) \tag{A.2e}$$

$$dU_{\text{price},i}^* = -\frac{1}{\rho}\log\left(\frac{(1-\alpha)\,(A_i)^{\frac{1}{1-\alpha}}\left(\frac{2\alpha}{\widetilde{b}_{K,i}}\right)^{\frac{\alpha}{1-\alpha}} + \rho\cdot\widehat{\text{assets}}_i^*}{(1-\alpha)\,(A_{row})^{\frac{1}{1-\alpha}}\left(\frac{2\alpha}{\widetilde{b}_{K,row}}\right)^{\frac{\alpha}{1-\alpha}} + \rho\cdot\widehat{\text{assets}}_i^*}\right) - \frac{\eta}{\rho}\log\left(\frac{\text{quality}_i}{\text{quality}_{row}}\right) \tag{A.2f}$$

$$\begin{aligned}\widehat{\text{value}}_i^* \quad = \quad & \left((1-\alpha)\,(A_{row})^{\frac{1}{1-\alpha}}\left(\frac{2\alpha}{\widetilde{b}_{K,row}}\right)^{\frac{\alpha}{1-\alpha}} + \rho\cdot\widehat{\text{assets}}_{row}^*\right)\cdot\left(\frac{1}{\rho\, n_{row}}\right)\cdot \\ & \left(\frac{(1-\alpha)\,(A_i)^{\frac{1}{1-\alpha}}\left(\frac{2\alpha}{\widetilde{b}_{K,i}}\right)^{\frac{\alpha}{1-\alpha}} + \rho\cdot\widehat{\text{assets}}_i^*}{(1-\alpha)\,(A_{row})^{\frac{1}{1-\alpha}}\left(\frac{2\alpha}{\widetilde{b}_{K,row}}\right)^{\frac{\alpha}{1-\alpha}} + \rho\cdot\widehat{\text{assets}}_i^*}\right)^{\frac{1}{\zeta}}\cdot\left(\frac{\text{quality}_i}{\text{quality}_{row}}\right)^{\frac{\eta}{\zeta}}\end{aligned} \tag{A.2g}$$

Changes in local steady-state asset wealth affect the remaining history-dependent steady-state levels according to,

$$\frac{\mathrm{d}\,L_i^*}{\mathrm{d}\,\widehat{\text{assets}}_i^*} = \begin{matrix}+\\-\end{matrix}\ \text{as}\ \frac{(1-\alpha)\,(A_i)^{\frac{1}{1-\alpha}}\left(\frac{2\alpha}{\widetilde{b}_{K,i}}\right)^{\frac{\alpha}{1-\alpha}} + \rho\cdot\widehat{\text{assets}}_i^*}{(1-\alpha)\,(A_{row})^{\frac{1}{1-\alpha}}\left(\frac{2\alpha}{\widetilde{b}_{K,row}}\right)^{\frac{\alpha}{1-\alpha}} + \rho\cdot\widehat{\text{assets}}_i^*}\ \begin{matrix}<\\>\end{matrix}\ 1-\zeta \tag{A.3}$$

$$\begin{aligned}\frac{\mathrm{d}\,\widehat{\text{value}}_i^*}{\mathrm{d}\,\widehat{\text{assets}}_i^*} \quad &= \quad \begin{matrix}+\\-\end{matrix}\ \text{as}\ \frac{(1-\alpha)\,(A_i)^{\frac{1}{1-\alpha}}\left(\frac{2\alpha}{\widetilde{b}_{K,i}}\right)^{\frac{\alpha}{1-\alpha}} + \rho\cdot\widehat{\text{assets}}_i^*}{(1-\alpha)\,(A_{row})^{\frac{1}{1-\alpha}}\left(\frac{2\alpha}{\widetilde{b}_{K,row}}\right)^{\frac{\alpha}{1-\alpha}} + \rho\cdot\widehat{\text{assets}}_i^*}\ \begin{matrix}<\\>\end{matrix}\ 1 \\ &= \quad \begin{matrix}+\\-\end{matrix}\ \text{as}\ \frac{A_i}{\widetilde{b}_{K,i}^{\alpha}}\ \begin{matrix}<\\>\end{matrix}\ \frac{A_{row}}{\widetilde{b}_{K,row}^{\alpha}}\end{aligned} \tag{A.4}$$

Focusing first on the land price equation, (A.4), a partial effect of an increase in asset wealth is to cause agents to increase their spending on housing services thereby increasing land prices. But the total effect includes in addition that changes in asset wealth affect steady-state population, (i.e. (A.3)). When normalized total factor productivity, $\frac{A}{\widetilde{b}_K^{\alpha}}$, is sufficiently low in locality i relative to *row*, increases in asset wealth lead to a higher steady-state population for locality i. Hence, both the "partial" and "population" effects of the increase in asset wealth are to raise locality i land prices.

On the other hand, when normalized total factor productivity is sufficiently high in locality i relative to *row*, the "partial" and "population" effects are in the opposite direction and so increases in asset wealth can lower steady-state locality i land prices. That the change in sign of the total derivative occurs at a lower value of normalized productivity for population, (A.3), than for land prices, (A.4), naturally follows: when the total derivative for population is exactly zero, the partial effect on land prices of an increase in asset wealth remains positive.

Focusing now on the population equation, consider the case where normalized total factor productivity is lower in i than in *row*. Recall that the assumption of Tiebout wealth sorting implies that $assets_i^*$ is the steady-state asset wealth of *both* i's residents and of potential migrants to i from *row*. The higher the asset wealth of potential migrants, the lower the utility loss from i's low productivity. Therefore the partial effect of an increase in asset wealth is to make i less unattractive and hence to increase i's population. This partial effect is greater the lower is i's productivity relative to that in *row*. Acting in an opposite direction is the partial effect of higher asset wealth on land prices: for a given population, higher asset wealth implies greater demand for housing services and hence higher land prices in turn making i more unattractive to potential migrants. As long as the left-hand side of the inequality in (A.3) is less than $1 - \zeta$, the partial effect dominates this latter "price" effect so that increases in asset wealth increase steady-state population. When the left-hand side of the inequality in (A.3) lies on the interval $[1 - \zeta, 1]$, productivity is i still lower than in *row*, but now the price effect dominates the partial effect so that increases in asset wealth decrease steady-state population.

Finally, consider the case where normalized total factor productivity is higher in i than in *row*. Here, the partial effect of an increase in asset wealth on population is negative: the higher the asset wealth of potential migrants, the lower the utility gain from i's high productivity. The negative partial effect of higher asset wealth on steady-state population via land prices remains. Together, these two partial effects imply that the total effect of an increase in asset wealth is to cause steady-state population to decrease. Note that this latter "partial" effect of higher asset wealth causing an increase in land prices is the opposite of the total effect of asset wealth on land prices discussed immediately above; the "reversal" is exactly because the total effect of asset wealth on steady-state population is negative.

B Local Growth with Frictionless Labor

An assumption of frictionless labor (i.e. $b_L = 0$) assures that utility *levels* will always be equal across localities. But frictionless labor does not imply that utility *flows* will be identical across localities; on the contrary, in general only in a long-run steady state will utility flows be equal. The key to the proof which follows is that equal utility flows across localities imply equal asset accumulation across localities but that together these two conditions over determine the dynamic system. Rather than equating utility flows instantaneously, frictionless labor implies an intertemporal tradeoff in the sense that living in some localities is associated with higher utility flows today while living in others is associated with higher asset accumulation today (and so higher utility flows in the future).

Suppose that utility flows are always equal across localities. It follows that asset accumulation must be equal as well (i.e. $\text{assets}_i(t) = \text{assets}_{row}(t)$ for all t); if not, individuals could increase their utility by living in a locality with higher asset accumulation for a time after which they switch to a different locality where their increased asset wealth allows them to finance a higher flow of output and land consumption. Recall that the budget constraint for individual asset accumulation is given by,

$$\frac{\mathrm{d}}{\mathrm{d}t}\text{assets}_{i,t} = r \cdot \text{assets}_{i,t} + w_{i,t} - c_{i,t} - p_{i,t}n_{i,t} \tag{B.1}$$

The first order conditions, (4a) and (4b), imply,

$$\frac{\mathrm{d}}{\mathrm{d}t}\text{assets}_{i,t} = (r-\rho) \cdot \text{assets}_{i,t} + w_{i,t}\left(K_{i,t}, L_{i,t}\right) - \rho \cdot \int_t^\infty w_{i,s}\left(K_{i,s}, L_{i,s}\right) \mathrm{e}^{-r(s-t)}\mathrm{d}s \tag{B.2}$$

In *row*, asset wealth grows at the rate of exogenous technological progress, x (which equals $r-\rho$). Hence the second two terms of the right hand side of (B.2) together must always sum to zero. Hence the future path of population in locality i must always satisfy,

$$\begin{aligned} \{L_{i,s}\}_{s=t}^\infty \text{ s.t.} \qquad & w_{i,t}\left(K_{i,t}, L_{i,t}\right) \\ - \quad & \rho \cdot \int_t^\infty w_{i,s}\left(K_{i,s}, L_{i,s}\right) \mathrm{e}^{-r(s-t)}\mathrm{d}s = 0 \end{aligned} \tag{B.3}$$

The instantaneous equating of utility levels across localities implies,

$$\mathrm{d}U_{\text{wealth},i,t} + \mathrm{d}U_{\text{price},i,t} + \mathrm{d}U_{\text{quality},i,t} = 0 \tag{B.4}$$

Using (16a) – (16c) to substitute, the time path of population must always satisfy,

$$\begin{aligned} \{L_{i,s}\}_{s=t}^\infty \text{ s.t.} \qquad & \tfrac{1}{\rho}\log\left(\frac{\int_t^\infty w_{i,s}(K_{i,s},L_{i,s})\mathrm{e}^{-r(s-t)}\mathrm{d}s + \text{assets}_{i,t}}{\int_t^\infty w_{row}(s)\mathrm{e}^{-r(s-t)}\mathrm{d}s + \text{assets}_{i,t}}\right) \\ + \quad & \zeta\int_t^\infty \log\left(\frac{p_{row,s}}{p_{i,s}\left(\{K_{i,v}\}_{v=s}^\infty, \{L_{i,v}\}_{v=s}^\infty\right)}\right)\mathrm{e}^{-\rho(s-t)}\mathrm{d}s \\ + \quad & \eta\int_t^\infty \log\left(\frac{\text{quality}_{i,s}}{\text{quality}_{row,s}}\right)\mathrm{e}^{-\rho(s-t)}\mathrm{d}s \qquad = 0 \end{aligned} \tag{B.5}$$

Assume that there exists a time path of population which satisfies (B.5). In general this will not be the same as a time path of population which satisfies (B.3). The system is over determined. Differentiating (B.3) with respect to t and substituting gives that wages always grow at the rate of exogenous technological progress, x, and hence normalized wages immediately jump to their steady state. With normalized wages at their steady state, the first and third terms of (B.5) are constant; hence normalized housing prices must also immediately jump to their steady-state level. Consider the case of the positive productivity shock shown in Figure 1. With gross capital stock instantaneously fixed, for wages to immediately jump to their steady state requires a decrease in population; but with asset wealth instantaneously fixed, for house prices to immediately jump to their steady state requires an increase in population. Similar contradictions arise from quality-of-life and capital shocks. While it may be possible to find a vector of parameters (including the size and nature of a shock) which do allow for the immediate satisfying of both (B.3) and (B.5), such a vector would have measure zero with respect to the parameter space.

Infinitely-lived agents residing in a low-utility-flow locale need not ever actually realize the future higher utility flows their asset accumulation will allow them. Particularly with a constant elasticity of intertemporal substitution, it is possible that such low-utility-flow residents may be willing to postpone indefinitely their gratification. More generally, life-cycle considerations and a decreasing marginal utility of (future) output consumption should eventually cause high-asset-wealth individuals to be less willing to delay gratification than low-asset-wealth individuals. If so, there would need to be a continual reshuffling of agents between high-utility-flow and low-utility-flow locales. With frictionless labor, such a reshuffling is costless. (As long as net migration were zero, such a reshuffling would also be costless in the model in the main text above.)

In the real world, one can find numerous examples of "localities" that allow for a tradeoff of low current utility flows for high future utility flows via high current asset accumulation (e.g. off-shore oil rigs, commercial fishing boats, investment banks, etc..)

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Table 1: Persistence of Population Flows

A. Serial Correlation Across Adjoining Decades: Population growth rate by decade, 1910-1990, for continental U.S. states and counties regressed on lagged value and a constant. All coefficients significant at 0.01 level.

		1910-20	20-30	30-40	40-50	50-60	60-70	70-80	80-90
States:	β	0.23	0.44	0.38	0.96	1.09	0.60	0.71	0.55
	R^2	0.19	0.24	0.21	0.46	0.70	0.73	0.35	0.52
Counties:	β	0.10	0.13	0.08	0.47	0.74	0.45	0.52	0.55
	R^2	0.03	0.01	0.02	0.12	0.46	0.32	0.27	0.42

B. Raw Correlation of Population Growth Across Decades: pairwise raw correlation of population growth rates by decade, 1900-1990, for continental U.S. counties.

	00-10	10-20	20-30	30-40	40-50	50-60	60-70	70-80	80-90
1900-1910	1								
1910-1920	0.19	1							
1920-1930	0.46	0.11	1						
1930-1940	-0.04	-0.01	0.15	1					
1940-1950	0.17	0.19	0.40	0.35	1				
1950-1960	0.10	0.12	0.27	0.35	0.68	1			
1960-1970	-0.15	0.04	0.04	0.31	0.45	0.57	1		
1970-1980	-0.10	-0.07	-0.04	0.32	0.16	0.26	0.52	1	
1980-1990	-0.10	-0.04	0.01	0.29	0.27	0.40	0.59	0.65	1

C. Raw Correlation of Net Migration Across Decades: pairwise raw correlation of net migration rates by decade, 1950-1990, for continental U.S. counties.

	50-60	60-70	70-80	80-90
1950-1960	1			
1960-1970	0.45	1		
1970-1980	0.14	0.49	1	
1980-1990	0.29	0.58	0.66	1

D. Raw Correlation of Employment Growth Across Decades: pairwise raw correlation of total employment growth rates by decade, 1950-1990, for continental U.S. counties.

	50-60	60-70	70-80	80-90
1950-1960	1			
1960-1970	0.34	1		
1970-1980	0.32	0.10	1	
1980-1990	0.38	0.17	0.45	1

Table 2: Serial Correlation of House Sales Price Growth and Income Growth

A. Median House Value Growth Rate: pairwise raw correlation of median house sales price growth rate by decade, 1950-1990, for continental U.S. counties.

	1950-1960	1960-1970	1970-1980	1980-1990
1950-1960	1			
1960-1970	0.00	1		
1970-1980	0.13	-0.06	1	
1980-1990	0.07	0.35	-0.24	1

B. Per Capita Income Growth Rate: pairwise raw correlation of per capita income growth rate by decade, 1959-1989, for continental U.S. counties.

	1959-1969	1969-1979	1979-1989
1959-1969	1		
1969-1979	0.11	1	
1979-1989	0.18	-0.28	1

C. Median Family Income Growth Rate: pairwise raw correlation of median family income growth rate by decade, 1950-1990, for continental U.S. counties.

	1949-1959	1959-1969	1969-1979	1979-1989
1949-1959	1			
1959-1969	0.20	1		
1969-1979	0.09	0.22	1	
1979-1989	0.20	0.22	-0.31	1

Table 3: Cross Correlation of Growth Rates by Decade

Pairwise raw correlation of growth rates for the given decade across continental U.S. counties. "House Value" corresponds to self-reported estimates of sales price by head of households in owner-occupied housing units.

A. 1950-1960	Net Migration	Employment Growth	Median House Value Growth	Median Family Income Growth ('49-'59)
Net Migration	1			
Employment Growth	0.88	1		
Median House Value Growth	0.17	0.23	1	
Median Family Income Growth ('49-'59)	0.09	0.15	0.39	1

B. 1960-1970	Net Migration	Employment Growth	Median House Value Growth	Per Capita Income Growth ('59-'69)
Net Migration	1			
Employment Growth	0.44	1		
Median House Value Growth	0.50	0.21	1	
Per Capita Income Growth ('59-'69)	-0.11	-0.21	0.29	1

C. 1970-1980	Net Migration	Employment Growth	Median House Value Growth	Per Capita Income Growth ('69-'79)
Net Migration	1			
Employment Growth	0.73	1		
Median House Value Growth	0.44	0.40	1	
Per Capita Income Growth ('69-'79)	0.19	0.24	0.34	1

D. 1980-1990	Net Migration	Employment Growth	Median House Value Growth	Per Capita Income Growth ('79-'89)
Net Migration	1			
Employment Growth	0.78	1		
Median House Value Growth	0.50	0.43	1	
Per Capita Income Growth ('79-'89)	0.44	0.49	0.59	1

Pairwise raw correlation of growth rates for the given decade across continental U.S. counties

Table 4: Population Flows Towards High House Prices

Net migration rate by decade, 1950-1990, for continental U.S. counties regressed on the log of the initial house price and a constant. Panels B and D also include the log and the log squared of inital per capita income (median family income for 1949) and the log and the log squared of initial population density. House sales price based on self-reported estimates by head of households in owner-occupied housing units. Standard errors in parentheses are robust to spatial correlation among the residuals. (See Conley, 1999; Rappaport, 1999b.)

A. Net Migration Regressed on Initial Median House Sales Price Only

	1950-1960		1960-1970		1970-1980		1980-1990
β =	0.021	β =	0.018	β =	0.007	β =	0.014
	(0.001)		(0.001)		(0.002)		(0.001)
R^2 =	0.27	R^2 =	0.13	R^2 =	0.02	R^2 =	0.14

B. Net Migration Regressed on Initial Median House Sales Price Controlling for Initial Income and Initial Employment Density.

	1950-1960		1960-1970		1970-1980		1980-1990
β =	0.010	β =	0.009	β =	0.017	β =	0.016
	(0.002)		(0.002)		(0.002)		(0.001)
R^2 =	0.34	R^2 =	0.22	R^2 =	0.10	R^2 =	0.17

C. Net Migration Regressed on Initial Median House Rental Price Only

	1950-1960		1960-1970		1970-1980		1980-1990
β =	0.022	β =	0.014	β =	0.003	β =	0.020
	(0.001)		(0.002)		(0.002)		(0.002)
R^2 =	0.20	R^2 =	0.09	R^2 =	0.00	R^2 =	0.11

D. Net Migration Regressed on Initial Median House Rental Price Controlling for Initial Income and Initial Employment Density.

	1950-1960		1960-1970		1970-1980		1980-1990
β =	0.005	β =	-0.001	β =	0.008	β =	0.023
	(0.002)		(0.002)		(0.003)		(0.003)
R^2 =	0.32	R^2 =	0.19	R^2 =	0.05	R^2 =	0.14

Table 6: Mobility Following a Productivity Shock

Numerical results for a positive change in total factor productivity such that new steady-state wage level is 1.05 times old level. For narrow capital share, (α = 0.30), this implies a 3.47% rise in TFP.

A. Low Capital Mobility (q_K^* = 3.24), Narrow Capital Share (α = 0.30)

Steady-state population ≈ 1.073; Steady-state housing price ≈ 1.115; Steady-state asset wealth ≈ 0.955

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)
Labor Mobility	Labor Friction	Initial Growth Rates (annual % rate at t= 0)			% of Gap Closed at Shock		Years to Close 75% of Distance to Steady State			Years to Close 95% of Distance to Steady State			Persist. of Pop Grwth
	(ω)	pop	wage	hsg val	wage	hsg val	pop	wage	hsg val	pop	wage	hsg val	
	1.32	0.06	0.08	0.04	69.5	54.7	153.5	3.6	65.6	325.8	36.3	238.5	0.996
	1.16	0.08	0.08	0.06	69.5	60.8	101.3	3.7	32.9	213.7	40.4	146.0	0.992
low	1.08	0.13	0.07	0.07	69.5	66.8	69.7	4.0	14.4	146.1	45.9	91.8	0.986
	1.04	0.18	0.07	0.08	69.5	72.1	50.7	4.6	4.1	106.6	50.0	61.0	0.976
	1.02	0.25	0.05	0.09	69.5	76.3	39.2	5.7	0	84.5	51.6	43.9	0.964
base	1.01	0.35	0.03	0.09	69.5	79.3	32.2	7.8	0	72.7	51.4	34.6	0.948
	1.005	0.48	-0.00	0.10	69.5	81.4	28.1	10.2	0	66.7	50.8	29.7	0.931
	1.0025	0.64	-0.05	0.10	69.5	82.7	25.8	11.9	0	63.7	50.4	27.3	0.916
high	1.00125	0.87	-0.11	0.11	69.4	83.6	24.8	12.6	0	62.3	50.1	26.1	0.902
	1.000625	1.17	-0.20	0.11	69.5	84.2	24.2	12.8	0	59.3	49.3	25.5	0.889

B. Base Capital Mobility (q_K^* = 1.56), Narrow Capital Share (α = 0.30)

Steady-state population ≈ 1.072; Steady-state housing price ≈ 1.117; Steady-state asset wealth ≈ 0.965

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)
Labor Mobility	Labor Friction	Initial Growth Rates (annual % rate at t= 0)			% of Gap Closed at Shock		Years to Close 75% of Distance to Steady State			Years to Close 95% of Distance to Steady State			Persist. of Pop Grwth
	(ω)	pop	wage	hsg val	wage	hsg val	pop	wage	hsg val	pop	wage	hsg val	
	1.32	0.06	0.13	0.04	69.5	56.1	149.1	2.2	60.3	317.6	20.9	230.0	0.996
	1.16	0.09	0.13	0.06	69.5	62.4	96.4	2.2	28.3	205.0	22.2	137.3	0.991
low	1.08	0.14	0.13	0.07	69.5	68.9	64.2	2.3	10.2	135.6	24.3	82.3	0.984
	1.04	0.20	0.12	0.08	69.5	74.6	44.6	2.5	0.5	93.6	27.3	50.5	0.974
	1.02	0.28	0.11	0.09	69.5	79.3	32.7	2.7	0	68.6	30.2	32.5	0.961
base	1.01	0.38	0.09	0.10	69.5	82.7	25.3	3.3	0	54.2	31.6	22.5	0.945
	1.005	0.52	0.06	0.11	69.4	85.1	20.8	4.4	0	46.4	31.8	16.8	0.927
	1.0025	0.69	0.02	0.11	69.5	86.8	18.1	5.8	0	42.3	31.6	13.7	0.909
high	1.00125	0.92	-0.04	0.11	69.5	87.8	16.5	7.0	0	40.3	31.3	12.1	0.894
	1.000625	1.23	-0.13	0.11	69.5	88.5	15.7	7.6	0	39.3	31.2	11.2	0.880

C. High Capital Mobility (q_K^* = 1.14), Narrow Capital Share (α = 0.30)

Steady-state population ≈ 1.071; Steady-state housing price ≈ 1.118; Steady-state asset wealth ≈ 0.979

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)
Labor Mobility	Labor Friction	Initial Growth Rates (annual % rate at t= 0)			% of Gap Closed at Shock		Years to Close 75% of Distance to Steady State			Years to Close 95% of Distance to Steady State			Persist. of Pop Grwth
	(ω)	pop	wage	hsg val	wage	hsg val	pop	wage	hsg val	pop	wage	hsg val	
	1.32	0.06	0.26	0.04	69.5	57.2	146.8	1.1	56.8	239.1	10.6	206.6	0.994
	1.16	0.10	0.25	0.06	69.4	63.7	93.7	1.2	25.1	188.1	10.8	132.2	0.988
low	1.08	0.15	0.25	0.07	69.5	70.4	60.9	1.2	7.5	129.9	11.2	76.9	0.981
	1.04	0.21	0.25	0.09	69.4	76.5	40.8	1.2	0	86.6	11.9	44.5	0.970
	1.02	0.31	0.24	0.10	69.5	81.6	28.3	1.2	0	59.6	13.0	25.9	0.956
base	1.01	0.43	0.22	0.10	69.4	85.5	20.5	1.3	0	42.9	14.5	15.2	0.936
	1.005	0.59	0.20	0.11	69.5	88.4	15.5	1.5	0	32.8	15.8	9.2	0.912
	1.0025	0.78	0.16	0.11	69.4	90.4	12.4	1.8	0	26.8	16.5	5.8	0.886
high	1.00125	1.05	0.10	0.12	69.5	91.7	10.5	2.4	0	23.6	16.5	3.9	0.863
	1.000625	1.37	0.02	0.12	69.5	92.6	9.3	3.1	0	21.9	16.5	2.8	0.846

Table 6: Mobility Following a Productivity Shock (continued)

Numerical results for a positive change in total factor productivity such that new steady-state wage level is 1.05 times old level. For broad capital share, (α = 0.60), this implies a 1.97% rise in TFP.

D. Low Capital Mobility (q_K* = 3.24), Broad Capital Share (α = 0.60)

Steady-state population ≈ 1.073; Steady-state housing price ≈ 1.115; Steady-state asset wealth ≈ 0.955

(1) Labor Mobility	(2) Labor Friction (ω)	(3) Initial Growth Rates (annual % rate at t= 0) pop	(4) wage	(5) hsg val	(6) % of Gap Closed at Shock wage	(7) hsg val	(8) Years to Close 75% of Distance to Steady State pop	(9) wage	(10) hsg val	(11) Years to Close 95% of Distance to Steady State pop	(12) wage	(13) hsg val	(14) Persist. of Pop Grwth
	1.32	0.03	0.12	0.03	39.5	49.1	168.0	23.0	85.3	350.7	85.1	268.5	1.004
	1.16	0.05	0.12	0.04	39.5	54.4	117.5	24.4	50.6	242.2	95.4	176.1	1.001
low	1.08	0.07	0.11	0.05	39.5	59.3	87.5	26.7	30.7	179.3	99.8	123.5	0.996
	1.04	0.09	0.10	0.06	39.4	63.5	70.1	29.4	19.2	144.8	99.3	94.9	0.991
	1.02	0.12	0.09	0.06	39.4	66.4	60.2	32.0	12.9	126.8	97.6	79.9	0.984
base	1.01	0.15	0.08	0.07	39.3	68.4	54.9	33.7	9.3	117.7	96.2	72.4	0.975
	1.005	0.19	0.06	0.07	39.4	69.5	52.0	34.5	7.4	113.2	95.4	68.6	0.966
	1.0025	0.23	0.04	0.07	39.4	70.3	50.5	34.9	6.3	110.9	94.9	66.7	0.958
high	1.00125	0.28	0.01	0.07	39.5	70.7	49.8	35.0	5.7	99.0	90.9	65.8	0.949
	1.000625	0.34	-0.03	0.07	39.4	70.9	49.5	35.1	5.5	85.7	79.8	64.5	0.941

E. Base Capital Mobility (q_K* = 1.56), Broad Capital Share (α = 0.60)

Steady-state population ≈ 1.062; Steady-state housing price ≈ 1.093; Steady-state asset wealth ≈ 0.977

(1) Labor Mobility	(2) Labor Friction (ω)	(3) Initial Growth Rates (annual % rate at t= 0) pop	(4) wage	(5) hsg val	(6) % of Gap Closed at Shock wage	(7) hsg val	(8) Years to Close 75% of Distance to Steady State pop	(9) wage	(10) hsg val	(11) Years to Close 95% of Distance to Steady State pop	(12) wage	(13) hsg val	(14) Persist. of Pop Grwth
	1.32	0.04	0.20	0.04	39.5	52.7	155.7	13.6	71.1	329.3	43.7	245.2	1.002
	1.16	0.06	0.19	0.05	39.3	58.5	104.0	14.1	37.9	217.9	48.8	152.2	0.999
low	1.08	0.09	0.19	0.06	39.3	64.3	73.0	14.8	18.9	150.8	54.9	97.7	0.994
	1.04	0.12	0.18	0.07	39.3	69.2	54.7	15.9	8.4	112.0	58.7	67.1	0.988
	1.02	0.15	0.17	0.07	39.3	72.9	44.0	17.4	2.6	90.5	59.6	50.4	0.981
base	1.01	0.19	0.16	0.08	39.5	75.5	37.8	18.8	0	79.0	59.1	41.6	0.972
	1.005	0.23	0.14	0.08	39.5	77.1	34.4	19.9	0	73.1	58.5	37.0	0.964
	1.0025	0.27	0.13	0.08	39.3	78.0	32.6	20.6	0	70.2	58.0	34.7	0.956
high	1.00125	0.31	0.11	0.08	39.2	78.6	31.7	20.8	0	68.8	57.8	33.6	0.949
	1.000625	0.37	0.07	0.08	39.4	78.9	31.1	21.0	0	64.2	57.3	33.0	0.941

F. High Capital Mobility (q_K* = 1.14), Broad Capital Share (α = 0.60)

Steady-state population ≈ 1.060; Steady-state housing price ≈ 1.096; Steady-state asset wealth ≈ 0.985

(1) Labor Mobility	(2) Labor Friction (ω)	(3) Initial Growth Rates (annual % rate at t= 0) pop	(4) wage	(5) hsg val	(6) % of Gap Closed at Shock wage	(7) hsg val	(8) Years to Close 75% of Distance to Steady State pop	(9) wage	(10) hsg val	(11) Years to Close 95% of Distance to Steady State pop	(12) wage	(13) hsg val	(14) Persist. of Pop Grwth
	1.32	0.05	0.38	0.04	39.4	55.6	148.5	6.9	61.2	279.8	20.3	229.0	0.998
	1.16	0.07	0.38	0.05	39.4	62.0	96.0	7.0	28.9	201.6	21.2	137.4	0.994
low	1.08	0.10	0.37	0.06	39.5	68.4	63.8	7.1	10.8	134.6	22.7	82.1	0.989
	1.04	0.14	0.37	0.07	39.3	74.1	44.3	7.4	1.1	92.5	25.2	50.2	0.981
	1.02	0.19	0.36	0.08	39.5	78.8	32.6	7.7	0	67.1	27.8	32.1	0.971
base	1.01	0.25	0.35	0.08	39.3	82.1	25.5	8.3	0	52.3	29.4	22.1	0.959
	1.005	0.31	0.33	0.09	39.4	84.4	21.3	9.0	0	43.9	29.9	16.7	0.945
	1.0025	0.36	0.31	0.09	39.4	85.8	18.9	9.6	0	39.5	29.8	13.7	0.934
high	1.00125	0.42	0.29	0.09	39.4	86.6	17.5	10.1	0	37.2	29.6	12.2	0.925
	1.000625	0.48	0.27	0.09	39.4	87.1	16.8	10.3	0	36.1	29.5	11.4	0.918

Table 7: Mobility Following a Quality-of-Life Shock

Numerical results for a positive change in quality of life such that individuals are willing to pay a 5% premium for housing services while still attaining their reservation level of utility.

A. Low Capital Mobility ($q_K^* = 3.24$), Narrow Capital Share ($\alpha = 0.30$)

Steady-state population ≈ 1.103; Steady-state asset wealth ≈ 0.975

(1) Labor Mobility	(2) Labor Friction (ω)	(3) Initial Growth Rates (annual % rate at t= 0) pop	(4) wage	(5) hsg val	(6) % Hsg Val Gap Clsd at Shock	(7) Local Wage Minimum level	(8) year	(9) Years to Close 75% Gap to Steady State pop	(10) hsg val	(11) Years to Close 95% Gap to Steady State pop	(12) hsg val	(13) Persist. of Pop Grwth
	1.32	0.05	-0.01	0.03	31.2	0.999	36.5	149.2	108.8	321.1	280.7	0.990
	1.16	0.07	-0.01	0.04	41.2	0.999	30.7	96.7	59.8	208.7	171.8	0.985
low	1.08	0.11	-0.01	0.05	51.3	0.999	25.5	64.4	31.0	140.1	106.7	0.976
	1.04	0.17	-0.03	0.06	60.4	0.998	21.1	44.5	14.8	99.1	69.0	0.964
	1.02	0.25	-0.04	0.07	67.9	0.997	17.2	32.0	5.8	75.2	47.5	0.947
base	1.01	0.36	-0.07	0.07	73.5	0.997	14.0	24.0	1.0	61.7	35.3	0.925
	1.005	0.51	-0.11	0.08	77.6	0.996	11.3	18.8	0	54.6	28.7	0.902
	1.0025	0.73	-0.17	0.08	80.5	0.995	9.1	15.3	0	51.1	25.3	0.879
high	1.00125	1.02	-0.25	0.08	82.5	0.994	7.2	13.1	0	49.4	23.7	0.860
	1.000625	1.43	-0.37	0.08	83.6	0.993	5.6	12.1	0	48.8	23.2	0.847

B. Base Capital Mobility ($q_K^* = 1.56$), Narrow Capital Share ($\alpha = 0.30$)

Steady-state population ≈ 1.102; Steady-state asset wealth ≈ 0.983

(1) Labor Mobility	(2) Labor Friction (ω)	(3) Initial Growth Rates (annual % rate at t= 0) pop	(4) wage	(5) hsg val	(6) % Hsg Val Gap Clsd at Shock	(7) Local Wage Minimum level	(8) year	(9) Years to Close 75% Gap to Steady State pop	(10) hsg val	(11) Years to Close 95% Gap to Steady State pop	(12) hsg val	(13) Persist. of Pop Grwth
	1.32	0.05	0.00	0.03	31.8	1.000	27.1	146.8	106.2	315.5	274.7	0.990
	1.16	0.07	-0.01	0.04	42.0	1.000	23.1	94.1	57.0	202.4	165.4	0.984
low	1.08	0.11	-0.01	0.05	52.6	0.999	19.5	61.6	28.4	132.7	99.6	0.976
	1.04	0.17	-0.02	0.06	62.2	0.999	16.4	41.6	12.4	90.2	61.0	0.964
	1.02	0.25	-0.03	0.07	70.1	0.998	13.7	29.1	3.7	64.3	38.6	0.948
base	1.01	0.37	-0.06	0.08	76.3	0.998	11.3	21.1	0	48.7	25.5	0.926
	1.005	0.53	-0.09	0.08	80.8	0.997	9.3	15.9	0	39.7	18.0	0.901
	1.0025	0.74	-0.15	0.08	84.0	0.996	7.6	12.4	0	34.8	13.6	0.876
high	1.00125	1.04	-0.23	0.09	86.1	0.995	6.0	10.1	0	32.4	11.3	0.855
	1.000625	1.45	-0.35	0.09	87.5	0.995	4.9	8.6	0	31.2	10.1	0.839

C. High Capital Mobility ($q_K^* = 1.14$), Narrow Capital Share ($\alpha = 0.30$)

Steady-state population ≈ 1.101; Steady-state asset wealth ≈ 0.992

(1) Labor Mobility	(2) Labor Friction (ω)	(3) Initial Growth Rates (annual % rate at t= 0) pop	(4) wage	(5) hsg val	(6) % Hsg Val Gap Clsd at Shock	(7) Local Wage Minimum level	(8) year	(9) Years to Close 75% Gap to Steady State pop	(10) hsg val	(11) Years to Close 95% Gap to Steady State pop	(12) hsg val	(13) Persist. of Pop Grwth
	1.32	0.05	0.00	0.03	32.1	1.000	18.3	145.5	104.7	> 232.8	> 221.5	0.990
	1.16	0.07	0.00	0.04	42.6	1.000	15.3	92.6	55.4	189.1	161.9	0.985
low	1.08	0.12	-0.01	0.05	53.5	1.000	13.2	59.9	26.8	128.8	95.8	0.977
	1.04	0.17	-0.01	0.06	63.4	1.000	11.4	39.7	10.9	> 72.1	> 56.4	0.964
	1.02	0.26	-0.02	0.07	71.8	0.999	9.6	27.0	2.3	58.2	33.6	0.947
base	1.01	0.38	-0.04	0.08	78.5	0.999	8.2	18.9	0	41.1	20.1	0.924
	1.005	0.54	-0.07	0.08	83.4	0.998	6.8	13.6	0	30.3	12.1	0.894
	1.0025	0.77	-0.12	0.08	87.0	0.998	5.7	10.1	0	23.7	7.5	0.861
high	1.00125	1.08	-0.19	0.09	89.5	0.997	4.6	7.8	0	19.9	4.8	0.832
	1.000625	1.49	-0.30	0.09	91.1	0.996	3.8	6.2	0	17.8	3.1	0.807

Table 7: Mobility Following a Quality-of-Life Shock (continued)

Numerical results for a positive change in quality of life such that individuals are willing to pay a 10% premium for housing services while still attaining their reservation level of utility.

D. Low Capital Mobility (q_K* = 3.24), Broad Capital Share (α = 0.60)

Steady-state population ≈ 1.103;   Steady-state asset wealth ≈ 0.975

(1) Labor Mobility	(2) Labor Friction (ω)	(3) Initial Growth Rates (annual % rate at t= 0) pop	(4) wage	(5) hsg val	(6) % Hsg Val Gap Clsd at Shock	(7) Local Wage Minimum level	(8) year	(9) Years to Close 75% Gap to Steady State pop	(10) hsg val	(11) Years to Close 95% Gap to Steady State pop	(12) hsg val	(13) Persist. of Pop Grwth
	1.32	0.05	-0.01	0.03	29.7	0.998	44.5	156.8	117.2	338.6	299.0	0.990
	1.16	0.07	-0.02	0.04	38.7	0.998	37.1	104.7	68.2	228.3	191.7	0.984
low	1.08	0.11	-0.03	0.05	48.0	0.996	30.4	72.8	39.0	162.7	128.7	0.975
	1.04	0.16	-0.06	0.06	55.8	0.995	24.7	53.3	22.4	125.5	93.7	0.963
	1.02	0.24	-0.09	0.07	62.0	0.994	19.9	41.4	13.0	105.4	74.9	0.946
base	1.01	0.34	-0.15	0.07	66.5	0.992	15.9	34.3	7.5	95.1	65.4	0.926
	1.005	0.48	-0.22	0.07	69.8	0.991	12.6	30.1	4.2	89.8	60.5	0.904
	1.0025	0.69	-0.34	0.08	71.8	0.990	10.0	28.0	2.3	87.3	58.4	0.885
high	1.00125	0.96	-0.50	0.08	73.4	0.989	7.9	27.0	1.1	86.0	57.2	0.871
	1.000625	1.36	-0.73	0.08	74.2	0.988	6.1	26.7	0.5	80.8	56.9	0.856

E. Base Capital Mobility (q_K* = 1.56), Broad Capital Share (α = 0.60)

Steady-state population ≈ 1.102;   Steady-state asset wealth ≈ 0.983

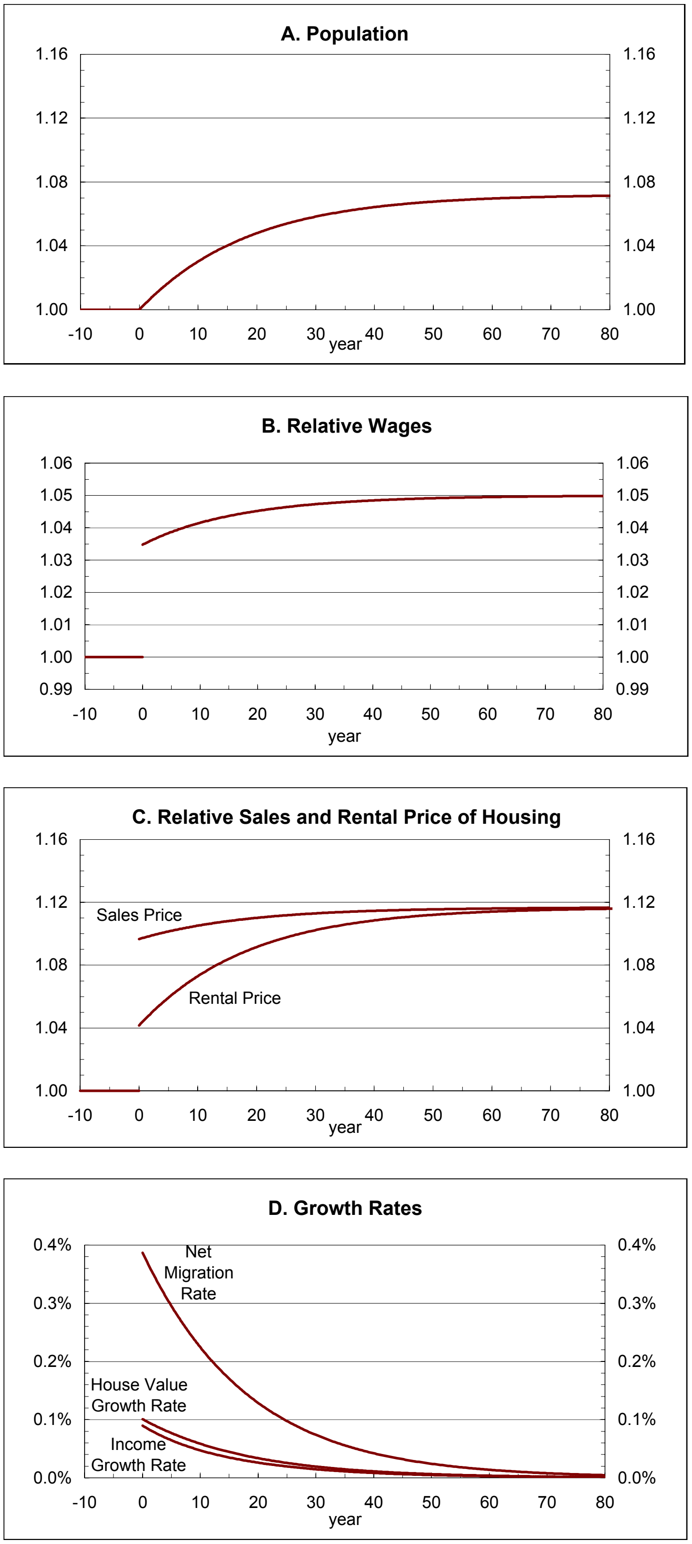
(1) Labor Mobility	(2) Labor Friction (ω)	(3) Initial Growth Rates (annual % rate at t= 0) pop	(4) wage	(5) hsg val	(6) % Hsg Val Gap Clsd at Shock	(7) Local Wage Minimum level	(8) year	(9) Years to Close 75% Gap to Steady State pop	(10) hsg val	(11) Years to Close 95% Gap to Steady State pop	(12) hsg val	(13) Persist. of Pop Grwth
	1.32	0.05	-0.01	0.03	31.0	0.999	33.1	150.4	110.1	323.5	283.3	0.989
	1.16	0.07	-0.02	0.04	40.7	0.999	28.1	98.0	61.1	211.3	174.5	0.984
low	1.08	0.11	-0.03	0.05	50.5	0.998	23.5	65.9	32.5	143.1	109.8	0.976
	1.04	0.17	-0.05	0.06	59.4	0.997	19.3	46.3	16.3	102.6	72.4	0.964
	1.02	0.24	-0.08	0.07	66.3	0.996	15.9	34.2	7.4	79.2	51.4	0.948
base	1.01	0.35	-0.13	0.07	71.7	0.994	13.0	26.7	2.4	66.3	39.7	0.929
	1.005	0.49	-0.20	0.08	75.3	0.993	10.5	22.0	0	59.5	33.7	0.908
	1.0025	0.69	-0.31	0.08	77.8	0.992	8.3	19.3	0	56.0	30.6	0.889
high	1.00125	0.96	-0.46	0.08	79.3	0.990	6.6	17.9	0	54.4	29.2	0.874
	1.000625	1.34	-0.68	0.08	80.5	0.989	5.2	17.3	0	53.5	28.4	0.860

F. High Capital Mobility (q_K* = 1.14), Broad Capital Share (α = 0.60)

Steady-state population ≈ 1.101;   Steady-state asset wealth ≈ 0.992

(1) Labor Mobility	(2) Labor Friction (ω)	(3) Initial Growth Rates (annual % rate at t= 0) pop	(4) wage	(5) hsg val	(6) % Hsg Val Gap Clsd at Shock	(7) Local Wage Minimum level	(8) year	(9) Years to Close 75% Gap to Steady State pop	(10) hsg val	(11) Years to Close 95% Gap to Steady State pop	(12) hsg val	(13) Persist. of Pop Grwth
	1.32	0.05	-0.01	0.03	31.8	1.000	21.5	146.6	106.0	287.0	265.2	0.990
	1.16	0.07	-0.01	0.04	42.1	0.999	18.5	93.9	56.8	201.8	164.8	0.984
low	1.08	0.11	-0.02	0.05	52.7	0.999	16.0	61.3	28.2	132.0	99.0	0.976
	1.04	0.17	-0.03	0.06	62.3	0.999	13.5	41.3	12.3	89.3	60.3	0.965
	1.02	0.25	-0.06	0.07	70.2	0.998	11.3	28.9	3.7	63.1	37.7	0.949
base	1.01	0.37	-0.09	0.08	76.3	0.997	9.4	21.1	0	47.2	24.7	0.928
	1.005	0.52	-0.16	0.08	80.7	0.996	7.8	16.1	0	37.9	17.2	0.904
	1.0025	0.72	-0.26	0.08	83.8	0.994	6.4	13.0	0	32.7	13.0	0.880
high	1.00125	1.00	-0.40	0.09	85.8	0.993	5.2	11.0	0	30.0	10.7	0.861
	1.000625	1.38	-0.61	0.09	87.1	0.992	4.1	9.8	0	28.7	9.6	0.845

Figure 1: Time-Series Response to a Positive Productivity Shock



Exogenous Parameters

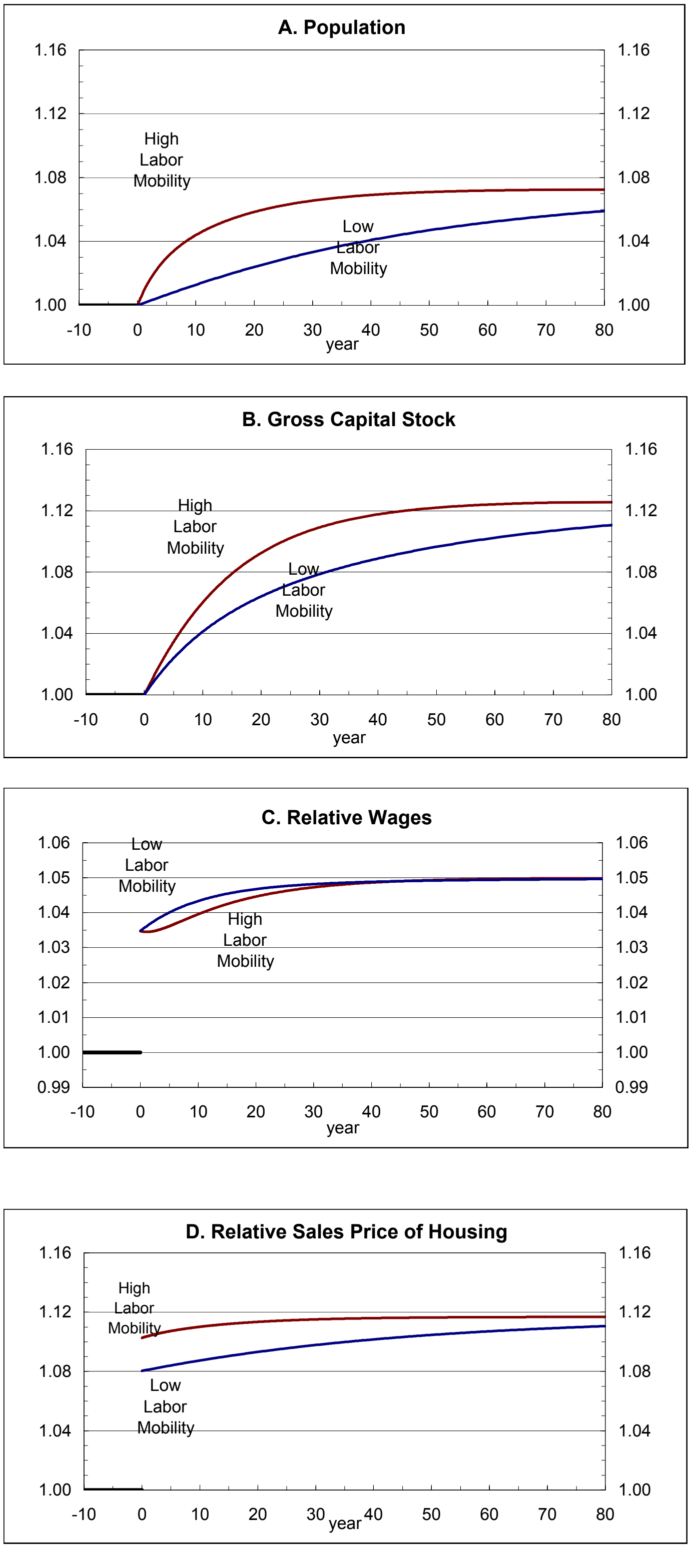
Figure assumes a shock which increases total factor productivity such that steady-state wages increase by 5%. With narrow capital share (α = 0.30), this implies a 3.47% rise in TFP.

Capital Share	α	= 0.30
Capital Depreciation Rate	δ	= 0.05
Housing Share	ζ	= 0.40
Time Preference	ρ	= 0.02
Technological Progress	x	= 0.02
Steady-State Shadow Value of Capital	q_K^*	= 1.56
Relative Wealth to Induce 1% Net Migration Rate	ω	= 1.01

Endogenous Results

Initial Net Migration	γ_L	= 0.38%
Initial Rate Gross Capital Formation	γ_K	= 0.68%
Initial Income Growth	γ_w	= 0.09%
Initial House Sales Price Growth Rate	γ_v	= 0.10%
Persistence of Net Migration	ar	= 0.947
Years to Close 95% of Distance from L_0 to L*	t^{95}	= 54.2
Initial Relative House Sales Price	$value^{t0}$	= 1.097
Steady-State Relative House Sales Price	value*	= 1.117
Steady-State Relative Asset Wealth	asst*	= 0.965
Steady-State Relative Population Density	L*	= 1.072

Figure 2: High vs. Low Labor Mobility: Response to a Positive Productivity Shock



Exogenous Parameters

Figure assumes a shock which increases total factor productivity such that steady-state wages increase by 5%. With narrow capital share (α = 0.30), this implies a 3.47% rise in TFP. Except for labor mobility, all parameters are the same as in Figure 1.

Relative Wealth to induce 1% Net Migration Rate	ω_{Low} = 1.08000 ω_{High} = 1.00125

Endogenous Results

Initial Net Migration	$\gamma_{L,Low}$ = 0.14% $\gamma_{L,High}$ = 0.92%
Initial Gross Capital Formation	$\gamma_{K,Low}$ = 0.56% $\gamma_{K,High}$ = 0.78%
Initial Income Growth	$\gamma_{w,Low}$ = 0.13% $\gamma_{w,High}$ = -0.04%
Persistence of Net Migration	ar_{Low} = 0.984 ar_{High} = 0.899
Years to Close 95% of Distance from L_0 to L*	t^{95}_{Low} = 135.6 t^{95}_{High} = 40.3
Initial Relative House Sales Price	$value_{Low}$ = 1.080 $value_{High}$ = 1.103
Steady-State Relative House Sales Price	$value^*_{Low}$ = 1.117 $value^*_{High}$ = 1.117
Steady-State Relative Asset Wealth	$asst^*_{Low}$ = 0.970 $asst^*_{High}$ = 0.960
Steady-State Relative Population Density	L^*_{Low} = 1.072 L^*_{High} = 1.073

Figure 3: Time-Series Response to a Positive Quality-of-Life Shock

Exogenous Parameters

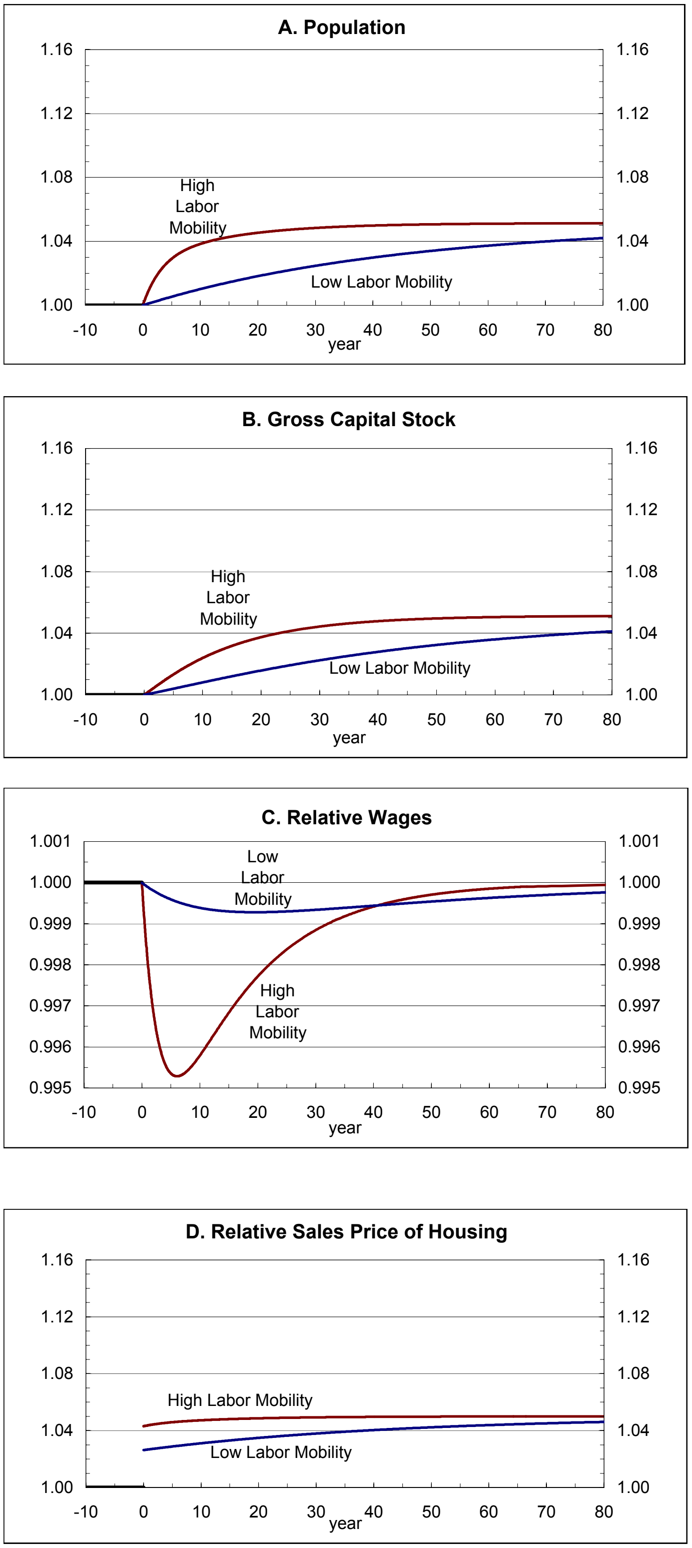
Figure assumes a shock which increases quality of life such that individuals are willing to pay 5% more for housing services while attaining reservation level of utility (so value* = 1.05). Parameters repeated below are the same as in Figure 1.

Capital Share	α	= 0.30
Capital Depreciation Rate	δ	= 0.05
Housing Share	ζ	= 0.40
Time Preference	ρ	= 0.02
Technological Progress	x	= 0.02
Steady-State Shadow Value of Capital	q_K^*	= 1.56
Relative Wealth to Induce 1% Net Migration Rate	ω	= 1.01

Endogenous Results

Initial Net Migration	γ_L	= 0.37%
Initial Rate Gross Capital Formation	γ_K	= 0.18%
Initial Income Growth	γ_w	= -0.06%
Initial House Sales Price Growth Rate	γ_v	= 0.08%
Persistence of Net Migration	ar	= 0.926
Years to Close 95% of Distance from L_0 to L*	t^{95}	= 48.7
Initial Relative House Sales Price	$value^{t0}$	= 1.038
Local Wage Minimum -- Level	w^{min}	= 0.998
Local Wage Minimum -- Year	t^{min}	= 11.3
Steady-State Relative Asset Wealth	asst*	= 0.991
Steady-State Relative Population Density	L*	= 1.051

Figure 4: High vs. Low Labor Mobility: Response to a Positive Quality-of-Life Shock



<u>Exogenous Parameters</u>

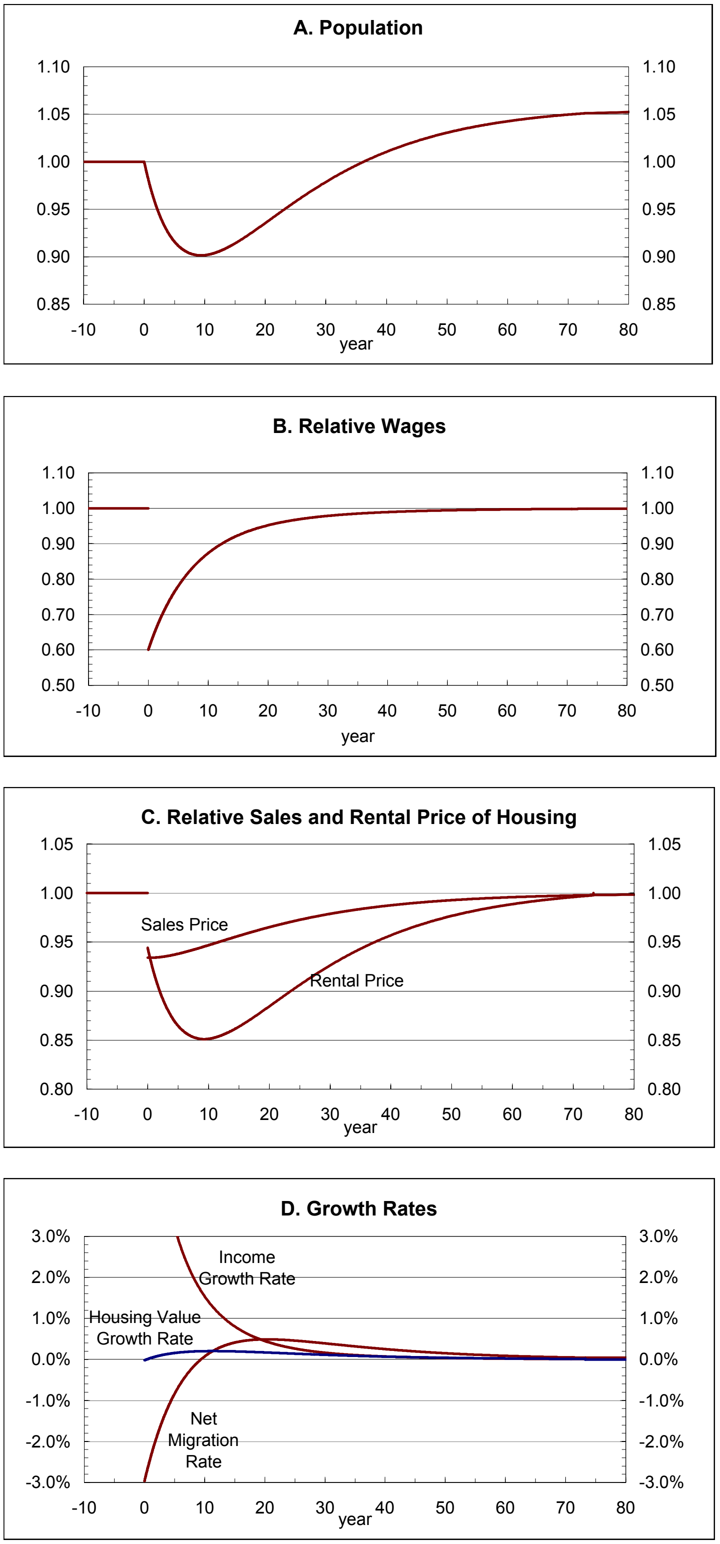
Figure assumes a shock which increases quality of life such that individuals are willing to pay 5% more for housing services while attaining reservation level of utility (so value* = 1.05). Except for labor mobility, all other parameters are the same as in Figures 1 and 3.

Relative Wealth to induce 1% Net Migration Rate	ω_{Low} =	1.08000
	ω_{High} =	1.00125

<u>Endogenous Results</u>

Initial Net Migration	$\gamma_{L,Low}$ =	0.11%
	$\gamma_{L,High}$ =	1.04%
Initial Gross Capital Formation	$\gamma_{K,Low}$ =	0.08%
	$\gamma_{K,High}$ =	0.27%
Initial Income Growth	$\gamma_{w,Low}$ =	-0.01%
	$\gamma_{w,High}$ =	-0.23%
Persistence of Net Migration	ar_{Low} =	0.976
	ar_{High} =	0.855
Years to Close 95% of Distance from L_0 to L*	t^{95}_{Low} =	132.7
	t^{95}_{High} =	32.4
Initial Relative House Sales Price	$value_{Low}$ =	1.026
	$value_{High}$ =	1.043
Local Wage Minimum -- Level	w^{min}_{Low} =	0.999
	w^{min}_{High} =	0.995
Local Wage Minimum -- Year	t^{min}_{Low} =	19.5
	t^{min}_{High} =	6.0
Steady-State Relative Asset Wealth	$asst^*_{Low}$ =	0.996
	$asst^*_{High}$ =	0.986
Steady-State Relative Population Density	L^*_{Low} =	1.050
	L^*_{High} =	1.051

Figure 5: Time-Series Response to a Negative Capital Shock



Exogenous Parameters

Figure assumes a shock which reduces initial physical capital stock such that income is at 60% of its steady-state level

Capital Share	α =	0.30
Capital Depreciation Rate	δ =	0.05
Housing Share	ζ =	0.40
Time Preference	ρ =	0.02
Technological Progress	x =	0.02
Steady-State Shadow Value of Capital	q_K^* =	1.56
Relative Wealth to Induce 1% Net Migration Rate	ω =	1.01

Endogenous Results

Initial Net Migration	γ_L =	-3.0%
Initial Rate Gross Capital Formation	γ_K =	25.1%
Initial Income Growth	γ_w =	8.4%
Initial House Sales Price Growth Rate	γ_v =	-0.0%
Initial Relative House Sales Price	value =	0.934
Population Density Minimum -- Level	L^{min} =	0.901
Population Density Minimum -- Year	t^{min} =	9.3
Steady-State Relative Asset Wealth	asst*=	0.439
Steady-State Relative Population Density	L* =	1.059