Housing Drag in the US Economy*

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First Version: February 2025
This Version: March 2026

Abstract

When productivity rises but housing supply fails to keep pace, income gains bid up rents rather than raising living standards. We develop a general equilibrium framework to measure this housing drag and calibrate it to U.S. data from 1980 to 2020. On average, each dollar of income growth delivered only 85 cents of welfare growth, with housing costs absorbing the rest. For the median household the loss was nearly half of all income gains; for the bottom decile, rising rents erased real consumption growth entirely. Across 717 commuting zones, what predicts drag is not the slope of local housing supply curves but whether housing supply per capita kept pace with local productivity. Optimal spatial redistribution yields negligible welfare gains; even a moderate expansion of housing supply yields substantial ones.

*We thank John Finlay, Brian Greaney, Juan Herreño, Hugo Lhullier and Shin Kikuchi for helpful comments. All errors are our own.
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INTRODUCTION

Over the last four decades, U.S. household incomes have grown substantially, but living standards have not kept pace. The translation of income gains into welfare improvements has been uneven across time, space, and the income distribution, and a central reason is the rising cost of shelter. Housing is both a necessity and, in many locations, difficult to expand. When incomes rise faster than the housing stock, the gains bid up rents rather than expand what households can consume, so that real income growth measured in non-housing prices overstates improvements in welfare.

A large body of work has identified zoning restrictions, regulatory barriers, and geographic constraints as the root causes of rising rents in high-productivity metro areas (Glaeser and Gyourko, 2003; Saiz, 2010; Hsieh and Moretti, 2019), with related work tracing the consequences for neighborhood composition (Diamond, 2016) and the spatial distribution of welfare gains across skill groups (Ganong and Shoag, 2017). Yet the aggregate implications of constrained housing supply for US economic growth remain largely unexplored.

This paper develops a framework to measure and explain this housing drag on US welfare growth. The central concept is simple. We separate income growth measured in non-housing prices from welfare growth measured in the full cost of living, and ask how much of the former fails to pass through to the latter. Letting I_t denote income per capita deflated by a non-housing price index and W_t money-metric welfare, we define the *housing drag elasticity* as

$$\mathcal{D} \equiv 1 - \frac{\Delta \log W}{\Delta \log I},$$

the fraction of income growth absorbed by rising prices for shelter rather than delivered as higher living standards. When shelter prices rise no faster than other prices, drag is zero; when they rise faster, as they have persistently since 1980, drag is positive.

A simple comparison of household income deflated by the non-housing CPI and by the full CPI suggests a drag elasticity of about 0.12 over 1980–2020. Had shelter prices risen no faster than other prices, American households would have been roughly 12 percent better off by 2020. This calculation requires nothing beyond widely available price indices and income data, but it holds only to a first order.

To sharpen the measurement, we develop an analytical framework with non-

homothetic preferences that allows housing's budget share to vary with income. We show that in general equilibrium, housing drag can be recovered from a small number of sufficient statistics—housing expenditure shares, rent growth, income growth, and a handful of well-known structural elasticities—making it easy to measure, decompose, and connect to the mechanisms emphasized in the urban and macroeconomic literatures.

Using these sufficient statistics and elasticities, our baseline quantitative results are stark. Between 1980 and 2020, we estimate an aggregate housing drag elasticity of about 0.15: each one percent increase in income measured in non-housing prices translated into only about 0.85 percent higher money-metric welfare.

Decomposing drag into its structural determinants, we find that exogenous demand shocks played essentially no role, suggesting that housing drag is purely a supply-side problem driven by unbalanced productivity growth.. Over 1980 to 2020, productivity in the non-housing economy grew substantially faster than in the housing sector, raising incomes and housing demand faster than the economy was able to expand housing supply.

The aggregate drag elasticity of 0.15 is, in a meaningful sense, a lower bound, reflecting primarily the experience of the top of the income distribution, who both spend a small share of their income on housing and have seen the most income growth. At the bottom of the distribution, households spend a much larger share of income on housing and have seen far less income growth, making them doubly exposed. The median household faced a drag elasticity of nearly 0.5, meaning roughly half of already modest income gains were absorbed by rising rents. At the bottom decile, housing costs consumed more than all real income growth since 1980, leaving that group with negative real consumption gains over four decades.

Income is not the only dimension along which housing drag varies: because housing markets are inherently local, geography is equally important. We therefore extend our framework into a quantitative spatial model, disaggregating housing drag across 717 US commuting zones. The heterogeneity is striking. Los Angeles has a drag elasticity above 0.3, meaning more than a third of local income growth was absorbed by rising rents; Chicago and Houston are near zero; Detroit is negative, meaning rents actually fell relative to non-housing prices. Yet this variation has little to do with population density or the level of local labor productivity: the cities with the highest drag are not simply the biggest or most productive ones.

What predicts cross-city drag is the balance between local productivity growth

and housing supply expansion. The natural prior is that cities with more elastic housing supply, with flatter supply curves, should exhibit lower drag. This prior is wrong, corroborating recent evidence from Louie, Mondragon, and Wieland (2025): across our 717 commuting zones, the correlation between standard housing supply elasticity estimates and housing drag is effectively zero. What matters is not the slope of local supply curves but whether housing supply per capita shifted outward fast enough to keep pace with local productivity growth. Cities that managed this balance passed productivity gains through to welfare; those that did not absorbed them in rents. For welfare, shifts of the supply curve are first order; slopes are second order.

These spatial results have direct policy implications. The finding that supply curve shifts dominate slopes suggests that policies which merely redistribute workers or resources across cities, moving the economy along its existing production possibility frontier, will do little. Our model confirms this: optimal spatial taxes that reallocate population across commuting zones yield negligible welfare gains. Instead, what is needed are policies that expand housing supply where productivity and hence housing demand is growing. Achieving zero-drag growth over 1980 to 2020 would have required raising housing quantity growth by roughly 0.3 percentage points per year and doubling housing-sector productivity growth—a substantial but quantifiable target for reform.

Our analysis speaks to several large literatures.

A first set of papers studies housing supply, land-use regulation, and the distribution of economic activity across cities. Seminal work measures the heterogeneity in housing supply elasticities and its geographic determinants (see, e.g., Saiz, 2010; Baum-Snow and Han, 2024), and links regulation and scarcity to house prices and construction. A related literature shows that housing constraints can affect the spatial allocation of labor and aggregate productivity by limiting migration into productive places (see, e.g., Hsieh and Moretti, 2019; Greaney, 2024), with an active debate on the quantitative magnitude of this "spatial misallocation" channel. We complement this literature by focusing on a different welfare channel: even holding the allocation of workers fixed, rising rents reduce the pass-through of productivity growth into consumption and welfare. In our spatial model we can separate these forces and show that the welfare gains from reallocating population are modest relative to the gains from shifting housing supply outward.

A second set of papers studies how relative price changes and non-homothetic demand shape welfare measurement (Baqaee and Burstein, 2023; Jaravel and Lashkari, 2024; Donald, Fukui, and Miyauchi, 2026). We build on these tools

and apply them to housing, showing that standard price indices systematically understate the burden of rising housing costs on lower-income households. We provide a quantitative decomposition of drag into its economic primitives, including housing-sector productivity, population growth, supply elasticities, and demand shifts, permitting counterfactuals hard to answer with reduced-form evidence alone, and verify that our conclusions hold under both utilitarian and Pareto-based welfare criteria (Baqaee and Burstein, 2026).

A third set of papers studies structural change and the long-run rise of services prices through Baumol-style mechanisms and multi-sector growth models (Ngai and Pissarides, 2007; Boppart, 2014; Comin, Lashkari, and Mestieri, 2021). Housing is a large and distinctive component of services: non-tradable, land-intensive, and heavily regulated. We isolate the housing component of this broader phenomenon and connect aggregate welfare accounting to spatial equilibrium, clarifying when rising rents reflect spatial misallocation versus aggregate housing scarcity, and showing that cross-sectional supply elasticities are the wrong statistic: what matters for welfare is whether the housing supply frontier shifts outward in high-demand places.

Section 2 presents the theoretical framework and Section 3 describes its quantification. Sections 4–5 measure housing drag in the aggregate, across the income distribution, and across US commuting zones. Section 6 evaluates policy. Section 7 concludes.

1. A First Look at Housing Drag in the Data

In this section, we introduce the housing drag concept and provide a first way of quantifying it in the data. To fix ideas, consider a consumer with income $\tilde{I}_t$ who faces a general cost of living index P_t of attaining a level of utility V_t, so that:

$$\tilde{I}_t = P_t(V_t, \tilde{r}_t, \mathbf{p}_t)V_t, \tag{1}$$

where $\tilde{r}_t$ is the price of residential housing services and $\mathbf{p}_t$ is a vector of all other consumption items.[1]

Define the consumer's *money-metric utility* as

$$W_t = P_0(V_t, \tilde{r}_0, \mathbf{p}_0)\, V_t, \tag{2}$$

the income that would be needed at base-period prices to attain the utility level

[1] Note that this could include future consumption at today's prices.

V_t achieved at period-t prices. If preferences are homothetic, P is independent of V and W_t is proportional to V_t. With income-dependent preferences, W_t and V_t can diverge, and W_t is the appropriate welfare measure (see Jaravel and Lashkari, 2024; Baqaee and Burstein, 2023).[2]

Totally differentiating equation (1), the change in money-metric welfare can be written as follows:

$$d \log W_t \approx d \log \frac{\tilde{I}_t}{\bar{p}_t} - \phi d \log \frac{\tilde{r}_t}{\bar{p}_t} \equiv d \log I_t - \phi d \log r_t, \tag{3}$$

which is exact if V is homothetic and holds up to first order otherwise. Here $\bar{p}$ denotes the average price of non-housing consumption, which we choose as the numeraire and ϕ denotes the share of *income* spent on housing services.[3] We define $I_t \equiv \tilde{I}_t / \bar{p}_t$ and $r_t \equiv \tilde{r}_t / \bar{p}_t$ as income and rents in terms of non-housing consumption.

Equation (3) decomposes welfare growth into the growth rate of purchasing power for non-housing consumption and an adjustment for relative changes in residential rents, weighted by their spending share. If residential rents grow faster than the price of non-housing consumption, housing represents a negative adjustment to purchasing power.

Figure 1 shows income in terms of non-housing consumption as solid lines, and income in terms of the full price index including the housing adjustment over time. All incomes are post-tax and redistribution household incomes. The blue and red lines use average household income data from the National Accounts (NIPA) and the Consumer Expenditure Survey (CEX), while the green lines show median household income from the Current Population Survey (CPS).

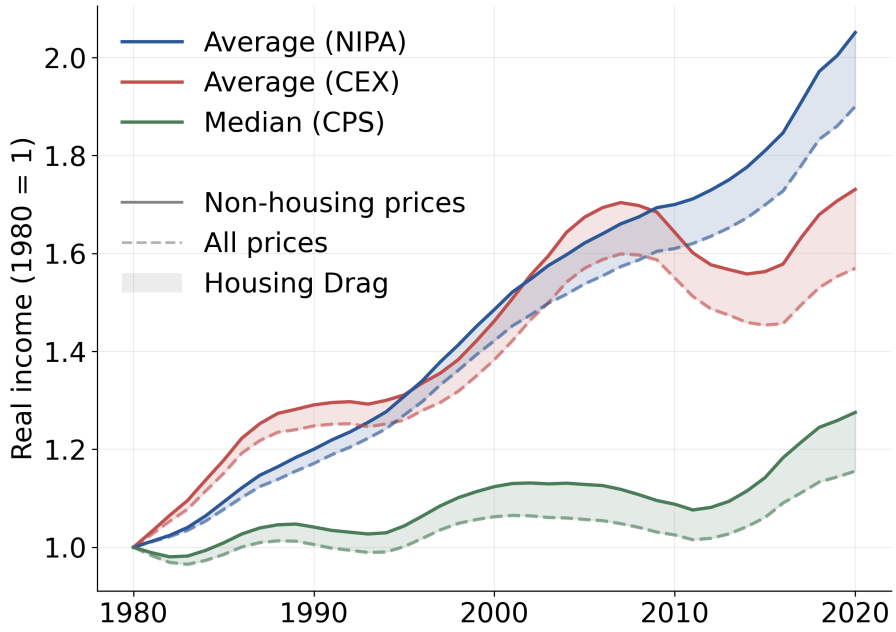
Figure 1 shows that housing prices have consistently grown faster than the price of all other consumption items, so that the dotted lines are below the solid ones for each data set. We refer to the gap between the lines as *housing drag*: the amount of welfare growth lost due to residential rents growing faster than non-housing prices. Equation (3) makes clear that the gap reflects both rents outgrowing the non-housing CPI and housing being the single largest consumption category for most households, so that ϕ tends to be large. Housing drag is a direct measure of the welfare cost of residential rents growing faster than other prices in the economy.

[2] There is ample evidence that preferences for housing services are income dependent (see, e.g., Albouy, Ehrlich, and Liu, 2016; Finlay and Williams, 2025).

[3] Notably this is not the share out of total consumption expenditure but out of total income. Note that savings can be thought of as one of the goods whose price is included in $\mathbf{p}$.

Figure 1 shows that housing drag differs across data sets and across the income distribution. For the average household in the NIPA, housing drag has lowered welfare growth between 1980 and 2020 by about 8 percentage points, compared to about 12 percentage points in the CEX. However, housing drag has cost the median household almost half of the welfare growth they would have experienced had residential rents grown in sync with other prices.

FIGURE 1: Housing Drag to a First Order



Notes: This figure shows income per capita from the BLS deflated by the CPI (gray line) and by the non-housing CPI (red line). Rents in the CPI reflect actual rents for renters and imputed rents for home owners.

Using equation (3), we define a first-order version of the main outcome of interest of our paper, *the housing drag elasticity*:

$$\mathcal{D}_t := 1 - \frac{d \log W_t}{d \log I_t} \approx \phi \frac{d \log r_t}{d \log I_t} := \mathcal{D}_t^{\text{FO}}.$$

Notably, the first order version holds preference weights fixed, but can be computed directly from data on housing shares, and residential rents and incomes deflated by a non-housing CPI.

The housing drag elasticity captures the housing drag per unit of income growth, and hence the loss of welfare to rising housing prices per unit of growth. The rest of the paper studies housing drag, its distributional consequences across the income distribution and regions, and considers possible ways of reducing it. In the next section, we begin with a simple analytical framework to characterize the structural determinants of housing drag.

2. THEORETICAL FRAMEWORK

In this section, we present our baseline analytical framework.

2.1 Environment

Consider an economy populated by a mass L of homogeneous agents and endowed with a mass of land T. Each worker inelastically supplies a single unit of labor. Workers own all land, their income combines labor income and land income. For simplicity, we assume that all workers own an equal share in the national land portfolio; we relax this choice later on. All output and input markets are competitive.

Agents have the following preferences over the consumption of housing services, h, and the numeraire good, c, which we think of as a composite of all non-housing consumption:

$$U^{\frac{\sigma-1}{\sigma}} = \Omega_h^{\frac{1}{\sigma}} h^{\frac{\sigma-1}{\sigma}} U^{\frac{\epsilon-1}{\sigma}} + \Omega_c^{\frac{1}{\sigma}} c^{\frac{\sigma-1}{\sigma}}, \tag{4}$$

Here, the parameter σ is the elasticity of substitution between housing and numeraire consumption, ϵ is the income elasticity, and Ω_h and Ω_c are preference shifters on each consumption category. To ensure stable preference over time, we follow Redding and Weinstein (2020) and impose the normalization $\Omega_c \Omega_h = 1$ throughout, so that $\Omega_c = \Omega_h^{-1}$.

Whenever the income elasticity of housing is unitary, so that $\epsilon = 1$, equation (4) collapses to the homothetic CES utility function.[4] Away from that limiting case, we impose the regularity condition $\frac{\epsilon-\sigma}{1-\sigma} > 0$ to ensure that U defines a well-behaved utility.

The economy has two two sectors of production: housing services and the numeraire good. The numeraire good is produced using a simple, labor-only production function with constant returns to scale and labor productivity A, so that $Y = AL$ is numeraire output. Housing services are produced using land, l, and the final good, x, with a Cobb-Douglas production function with final good share $\alpha \in (0, 1)$ and total factor productivity $\tilde{Z}$, so that $H = \tilde{Z} l^{\alpha} t^{1-\alpha}$.

Definition. *An equilibrium consists of (i) a utility index, V, (ii) housing expenditure shares, ϕ, (iii) total housing supply, H, (vi) income per capita, (v) residential rents r such*

[4] All our results are robust to using other non-homothetic preference aggregators.

that households maximize utility,

$$V^{1-\sigma}\Omega_c + V^{\epsilon-\sigma}\Omega_h r^{1-\sigma} = I^{1-\sigma} \quad \textit{and} \quad \frac{\phi}{1-\phi} = \frac{\Omega_h}{\Omega_c} V^{\epsilon-1} r^{1-\sigma},$$

the representative firm in the housing services sector maximizes profits,

$$H = \bar{H} r^{\kappa} \quad \textit{where} \quad \bar{H} = \tilde{Z}^{\frac{1}{1-\alpha}} T \alpha^{\frac{\alpha}{1-\alpha}},$$

for $\kappa := \frac{\alpha}{1-\alpha}$ denoting the housing supply elasticity, the representative firm in the numeraire sector maximizes profits, $w = A$, and housing markets clear, so that $rH = \phi IL$, where total income combines labor and land returns, $IL = AL + rH/(1+\kappa)$.

Note that when $\epsilon \neq 1$, so that preferences are non-homothetic, then indirect utility V does not adequately measure welfare over time (see Baqaee and Burstein, 2023; Jaravel and Lashkari, 2024). We use the money-metric welfare measure throughout to measure changes in real income, which maps changes in the utility index V into income growth at initial-period prices and preferences.

The framework features a flexible non-homothetic demand system for housing and numeraire consumption that has been widely used to study sectoral reallocation in models of structural change (see Comin et al., 2021); Finlay and Williams (2025) recently applied it to housing and non-housing. The supply side and income process are more stylized: we abstract from asset holdings and intertemporal consumption smoothing, including through home ownership. As we show in the next section, measuring housing drag in general equilibrium requires only the demand system and observable data on incomes, rents, and expenditure shares. Supply-side structure only becomes relevant to decompose housing drag into its structural determinants.

2.2 Theoretical Results

Conceptually, housing drag depends on which shocks drive income growth in the economy. We begin by characterizing the housing drag elasticity to an income shock that originates from labor productivity gains alone.

Proposition 1 (Housing Drag Elasticity of Labor Productivity Growth)**.** *Consider an equilibrium of the economy defined above. The housing drag associated with a small shock to labor productivity is given by:*

$$\mathcal{D}^A \equiv \phi \frac{\partial \ln r / \partial \ln A}{\partial \ln I / \partial \ln A} = \frac{\phi\chi}{\kappa + (1-\phi)\sigma + \phi\chi} \in (0,1), \tag{5}$$

where $\chi := 1 + \frac{(1-\epsilon)(1-\phi)(1-\sigma)}{\sigma-1+\phi(1-\epsilon)}$.

The special case of Proposition 1 with Cobb-Douglas preferences and inelastic housing supply helps understand the essence of the productivity-driven housing drag. In this case, the housing drag expression collapses to a constant housing expenditure share ϕ. So at its essence, housing drag captures that labor productivity growth only lowers prices for a share $1-\phi$ of consumer spending, while raising housing demand which in turn raises residential rents unless housing supply can respond enough to keep rents stable.

More generally, the key mechanism is that as labor productivity rises, workers get richer and spend a fraction of their income on housing. Since the economy's ability to produce housing is not changing, the endogenous housing supply expansion reflects only more intensive use of existing land as captured by κ. As long as $\kappa < \infty$ increasing demand cannot be met with proportional increases in supply, raising rents faster than income. As a result, the income growth translates less than one-for-one into real consumption increases.

Productivity-driven housing drag is zero in two special cases. First, when housing and numeraire are perfect substitutes: in this case, workers substitute away from residential housing as they become richer at a speed that ensures that residential rents are constant relative in terms of the numeraire. Second, when housing supply is infinitely elastic, so that $\kappa \to \infty$. In this case, residential rents are constant in terms of the numeraire as the economy grows. In both these limit cases, all productivity-driven income growth outside the housing sectors passes into real consumption one-for-one without any loss, or *drag*.

Proposition 1 also has a set of other instructive limits. If the housing share is 1, housing drag is $1/(1+\kappa)$: the rate at which labor productivity growth can raise welfare depends entirely on the slope of the housing supply curve; as $\kappa \to 0$, labor productivity growth becomes irrelevant for welfare growth. Furthermore, non-homothetic housing demand lowers drag in the economy. The lower the income elasticity of housing demand, ϵ, the lower is drag: if consumers substitute away from housing strongly as the get richer, housing drag shrinks.[5]

The message of Proposition 1 is stark: if productivity growth originates mainly in the non-housing sector, then eventually this productivity growth becomes unable to raise living standards of Americans.

The mechanism behind Proposition 1 is related to the well-known Baumol *cost-disease* effect (see Baumol, 1967). In Baumol (1967), there are two sectors that

[5]Note that χ is a non-homothetic adjustment term that is 1 whenever preferences are homothetic so that $\epsilon = 1$.

experience unbalanced productivity growth. Since labor can move freely across sectors, the lower growth ("stagnating") sector needs to pay workers the market wage, raising its costs; in addition, as the economy gets richer demand for both sectors rises, forcing the stagnating sector to produce more and more despite lagging productivity. In our context, there is no factor mobility, and the effect works through demand alone: as workers get richer they increase their housing spending thereby bidding up rents. This could be described as the *demand* disease part of the Baumol's cost disease.[6] Proposition 1 represents a generalization of this logic taking into account consumer ability to substitute away from housing, their changing preferences as they grow richer, the slope of the housing supply curve and changes in housing expenditure shares.

The formula in Proposition 1 can be computed using widely-available elasticities for the US economy. For all households, using CEX data, Finlay and Williams (2025) estimate $\sigma = 0.33$ and $\epsilon = 0.75$, while Baum-Snow and Han (2024) estimates $\kappa = 0.4$. The Consumer Expenditure Survey suggests that the residential rent share out of income of the average American was 25% in 2020. Plugging these numbers into Proposition 1 suggests a housing drag on the US economy of about 0.33. This suggests, all else equal, that a 1% increase in income generated through productivity improvements outside of the housing sector translates into a 0.67% increase in real consumption for the average American, all else equal.

However, the realized housing drag in the economy depends on a collection of shocks. In particular, changes in preference for housing and non-housing, changes in housing sector productivity, and changes in the total number of workers all influence the measured housing drag- that is, the gap between real GDP in non-housing consumption and real GDP in terms of the full consumption basket shown in Figure 1.

Proposition 1 presents the full housing drag elasticity.

Proposition 2 (Housing Drag Elasticity)**.** *Consider an equilibrium of the economy defined above. Given small shocks to all fundamentals, the housing drag on the economy*

[6]The two are easy to disentangle empirically: Baumol's cost-disease works through factor mobility. It predicts that the employment share of the stagnating sector converges to 1 as more and more workers are needed to produce the demanded quantity despite slower productivity growth. Yet, empirically, the fraction of workers employed in the construction and housing sectors has remained roughly constant since 1980, pointing at a demand instead of a cost disease in housing. This corroborates direct evidence from Goolsbee and Syverson (2023) who find that rising wages in the construction sector are not the explanation for the stagnation in measured housing sector productivity.

is given by:

$$\mathcal{D} = \mathcal{D}^A \left[1 - \frac{1}{\chi}\frac{d\ln Z}{d\ln I} + \frac{(1-\phi)(1-2\sigma+\epsilon)}{\chi((1-\sigma)+\phi(\epsilon-1))}\frac{d\ln \Omega_h}{d\ln I}\right] - \frac{1-2\phi}{1-\sigma}\frac{d\ln \Omega_h}{d\ln I} \tag{6}$$

where $Z \equiv \tilde{Z}/L$ *and* χ *is defined in Proposition 1.*

Proposition 2 shows how changes in preferences, housing productivity, and population growth interact with labor productivity growth to generate the total housing drag in the economy. The housing drag elasticity consists in two parts: the productivity-driven housing drag elasticity from Proposition 1 with a multiplier and an additional additive effect through changes in preference weights. Recall that $\Omega_h\Omega_c = 1$, so that an increase in one weight implies a decreases in the other.

Exogenous increases in housing supply through changes in the productivity of the housing reduce drag; population growth on its own raises the drag. This is intuitive: shifting out the housing supply curve lowers residential rents, alleviating the "demand disease" that puts upward pressure on them. Population growth on the other hand adds housing demand, further bidding up rents.

Since housing supply per capita is what matters for individual welfare, we henceforth define Z as the productivity with which the economy transforms land and the final good into housing per-capita. All else equal, growth in Z acts like a multiplicative dampening factor on productivity driven housing drag, $\mathcal{D}_A$.

The preference channel operates through two terms. The first, inside the multiplier on $\mathcal{D}^A$, captures the equilibrium rent response to changing Ω_h,; and the second, outside the multiplier, reflects the direct welfare effect of preference changes at given prices. Since $\sigma < \epsilon$, the multiplier on growth in Ω_h is positive, so that growth in Ω_h raises housing drag. This part captures that, all else equal, increases in Ω_h raises the expenditure of housing and hence add to rent price pressure.

The second term captures the direct welfare effect of the preference shift at given prices and income. Increasing Ω_h raises housing demand, reducing utility in proportion to ϕ, but under the normalization it simultaneously lowers Ω_c, reducing numeraire demand and raising utility in proportion to $1-\phi$. When $\phi < 1/2$, the second effect dominates and the preference shift partially offsets the rent pressure from the first term.

2.3 Limit: Housing Drag as a Growth Bottleneck

Propositions 1 and 2 show that the housing drag elasticity depends critically on the housing share of income, ϕ. We now investigate whether sustained economic

growth can itself push ϕ upward over time, and what this implies for long-run living standards. The next proposition characterizes the limiting behavior of the economy under sustained growth in fundamentals in continuous time, where the first-order results in Propositions 1 and 2 are exact.

Proposition 3 (Limiting pass-through)**.** *Assume $\sigma < \epsilon < 1$ and that fundamentals evolve continuously, $A_t = A_0 e^{g_A t}$, $Z_t = Z_0 e^{g_Z t}$, and $\Omega_{h,t} = \Omega_{h,0} e^{g_{\Omega_h} t}$. Define the following "housing pressure index" $\mathcal{H}$:*

$$\mathcal{H} \equiv \frac{1 - 2\sigma + \epsilon}{1 - \sigma} g_{\Omega_h} - (1 - \epsilon) g_A + (1 - \sigma) \frac{g_A - g_Z}{1 + \kappa}. \tag{7}$$

1. *A balanced-growth path with $\lim_{t\to\infty} \phi_t \in (0, 1)$ exists if, and only if, $\mathcal{H} = 0$.*
2. *If $\mathcal{H} > 0$, then $\lim_{t\to\infty} \phi_t = 1$, and the housing drag elasticity converges to*

$$\lim_{t\to\infty} \mathcal{D}_t = \begin{cases} 1 & \text{if } \kappa = 0, \\ \dfrac{1}{1+\kappa}\left(1 - \dfrac{g_Z}{g_A}\right) + \dfrac{g_{\Omega_h}}{(1-\sigma) g_A} & \text{if } \kappa > 0. \end{cases}$$

The housing pressure index $\mathcal{H}$ captures whether long-run growth in housing demand outpaces the economy's capacity to increase per-person housing supply without rents growing faster than the price of non-housing consumption. The numerator of the final term, $g_A - g_Z$, represents the net growth in demand factors relative to housing productivity: faster labor productivity growth (g_A) raises housing demand, while faster housing productivity growth (g_Z) relaxes supply constraints. The denominator $1 + \kappa$ measures how "costly" lagging housing productivity growth is: if housing is very elastic, supply can respond without shifts in the supply curve making the productivity growth gap less welfare relevant.

The remaining terms capture demand growth through preferences and non-homotheticity. The first term reflects that increases in the consumption weight on housing always raise housing pressure. The second reflects that if the income elasticity of housing is below 1, income growth lowers housing pressure by shifting consumption towards the numeraire.

When $\mathcal{H} > 0$, housing demand grows persistently faster than can be accommodated without rising rents, pushing the housing share toward one. The limiting drag depends on the supply elasticity κ. When $\kappa = 0$, no additional housing can be built regardless of how high rents rise. Rising rents then feed directly into income through land ownership, which raises housing demand further, which raises rents again. This cycle causes income growth to accelerate beyond the rate of productivity growth, but every income increment is absorbed by rents. As a

result, the housing drag on the economy converges to one. In this limit, none of the labor productivity gains in the economy translate into higher living standards.

When $\kappa > 0$, then rent increases translate partly into additional housing construction. This supply response limits the feedback loop between rents and income: although nearly all income is eventually spent on housing, rents do not spiral faster than productivity growth. As a result, long-run housing drag depends not only on the supply elasticity but also on whether other forces add or relieve pressure on the housing market.

This result connects the housing drag analysis to long-run growth dynamics. Proposition 1 showed that the housing supply elasticity κ governs the rent response to income growth; Proposition 3 shows that sustained rent pressure pushes the economy toward a regime where this elasticity determines housing drag in the limit. We now use this analytical framework to quantify housing drag in the US economy and decompose it into its structural drivers.

3. QUANTIFICATION

In this section, we describe how to take our analytical framework to the data.

3.1 Data

Given three structural parameters (σ, ϵ, and κ), we can invert the model's equilibrium conditions to recover labor productivity A, housing productivity Z, and the preference weight on housing Ω_h using data on income, residential rents, and the housing share out of income.

We obtain the requisite data from the Consumer Expenditure Survey (CEX) for five benchmark decades (1980, 1990, 2000, 2010, 2020), where each benchmark is a three-year centered average.[7] We map observational units in the model to households in the data, since housing is a household-level decision. We use post-tax and post-redistribution income since to accurately measure households' disposable income. To cover the entire economy, including renters and owners, we measure housing spending as the sum of actual rent payments and the annualized estimated rental value of owned homes ("imputed rent"). The rental

[7] Because the continuous CEX begins in 1984, the 1980 benchmark incorporates back-extrapolated values for 1977–1983 based on log-linear regressions using NIPA aggregates (DPI per household and PCE Housing per household) and CPS household counts as predictors; all other benchmarks use observed data only.

price index is the Consumer Price Index (CPI) for Shelter. We deflate income and rental prices by the CPI for all items less shelter ("non-housing CPI"). The Data Appendix provides more details in data construction.

TABLE 1: The Benchmark Data

Year	L	I	r	ϕ	$\mathcal{D}^{FO}_{t-1,t}$	$\mathcal{D}^{FO}_{1980,t}$
1980	1.00	1.00	1.00	0.24		
1990	1.15	1.29	1.15	0.22	0.13	0.13
2000	1.30	1.46	1.24	0.23	0.13	0.13
2010	1.44	1.64	1.25	0.22	0.02	0.11
2020	1.57	1.73	1.41	0.26	0.50	0.15

This table shows the data used in the calibration of the aggregate model. All nominal variables are deflated by the non-housing CPI. L denotes the total number of households, I denotes income per household, r denotes the housing CPI, and ϕ denotes the housing share out of income. The data come from the Consumer Expenditure Survey; data for years before 1984 are imputed using corresponding NIPA data. Figures represent averages around that year of three years on either side. The first three columns are normalized so that 1980 = 1.

Table 1 shows the data used in our benchmark calibration. The average household in the CEX saw their income grow by 73% between 1980 and 2020, when denominated in terms of non-housing consumer prices. The price of housing services increased substantially relative to the non-housing CPI, growing almost 41% since 1980. The share of the average's household's income spent on housing hovered around 22-26%.

We probe the robustness of our results along several dimensions in the Appendix. Most importantly, we construct a dataset using NIPA aggregates, with Disposable Personal Income per household as the income concept and the BEA's published PCE Housing Services aggregate for the expenditure share, all deflated with internally consistent PCE price indices. The NIPA variants provide an independent check that does not rely on the CEX and uses the BEA's Fisher-ideal chain-weighted prices rather than BLS fixed-basket CPI indices. In the Appendix, we also show versions that uses renter-only data and raw data without smoothing or imputation.

Note that the data in Table 1 are sufficient to compute the "first-order" pass-through equation presented in Section 1. In the last two columns, we show this first-order housing drag elasticity computed decade-by-decade, and relative to 1980.

3.2 Structural Elasticities

The framework introduced in Section 1 has three key elasticities. The elasticity of substitution between housing and numeraire consumption, σ, the income elasticity of housing demand, ϵ, and the housing supply elasticity, κ. All three elasticities have been estimated by several papers in the literature which we use to obtain values for them.

We obtain the housing demand elasticities from Finlay and Williams (2025) who carefully estimate the parameters of the non-homothetic CES utility function using US data over the same time period as our study. They provide estimates using the CEX microdata that underlies the data in Table 1. For the full CEX sample including renters and owners, these estimates are $\sigma = 0.33$ and $\epsilon = 0.75$ and we use them throughout the paper.

We obtain the "micro" housing supply elasticity from Baum-Snow and Han (2024). Baum-Snow and Han (2024) report unit, floorspace, and land development responses to house prices at the zip code tabulation area level. We interpret these elasticities as the slope of the housing supply curve. Through the lens of our model, the elasticity maps to the land share of local housing production, α. In our baseline exercise, we use the nationwide average of the unit elasticities, which is $\kappa = 0.4$; we show robustness with respect to this parameter in the Appendix.

3.3 Calibrating Model Fundamentals

Under the normalization $\Omega_{c,t} = \Omega_{h,t}^{-1}$, the indirect utility function and expenditure share condition become:[8]

$$\Omega_{h,t}^{-1} V_t^{1-\sigma} + \Omega_{h,t} V_t^{\varepsilon-\sigma} r_t^{1-\sigma} = I_t^{1-\sigma} \quad \text{and} \quad \frac{\phi_t}{1-\phi_t} = \Omega_{h,t}^2 \, V_t^{\epsilon-1} \, r_t^{1-\sigma}.$$

Using the housing share to substitute into the indirect utility equation yields:

$$V_t = \Omega_{h,t}^{1/(1-\sigma)} \, (1-\phi_t)^{1/(1-\sigma)} \, I_t.$$

This expression is intuitive. It shows that the utility index falls when the housing share, ϕ, rises *holding preference weights fixed*. For fixed preference weights, a rise in the housing share *must* reflect an increase in residential rents unrelated to preferences, such as through population growth.

[8] This normalization is required for stable preferences and hence to compare the utility index over time.

While indirect utility depends on the preference weight $\Omega_{h,t}$ in addition to the expenditure share and income, $\Omega_{h,t}$ can be recovered from observables. Substituting the expression for V_t into the expenditure share condition and re-arranging yields:

$$\Omega_{h,t} = \left[\frac{\phi_t}{(1-\phi_t)^{(\epsilon-\sigma)/(1-\sigma)}} I_t^{1-\epsilon} r_t^{\sigma-1} \right]^{(1-\sigma)/(1-2\sigma+\epsilon)}.$$

The term $\Omega_{h,t}$ can hence be computed period-by-period from data on housing shares, incomes, and rents. Using $\Omega_{h,t}$, we can then solve for the utility index using the same empirical moments.

As noted earlier, with income-dependent preferences, changes in indirect utility are not an appropriate measure of changes in real consumption (see Baqaee and Burstein, 2023; Jaravel and Lashkari, 2024). Instead, we measure welfare using the money-metric, which answers the questions "What is the increase in income at constant prices and preferences that the observed increase in the utility index V_t corresponds to?". Following equation (2), it can be computed as the factor W_t by which one would have to multiply initial-period income, I_0, to achieve the period-t level of indirect utility, V_t, at the initial-period prices r_0 and preference weights $\Omega_{h,0}$:

$$\Omega_{h,0}^{-1} V_t^{1-\sigma} + \Omega_{h,0} V_t^{\varepsilon-\sigma} r_0^{1-\sigma} = W_t^{1-\sigma} I_0^{1-\sigma},$$

when preferences are homothetic, so that $\epsilon = 1$, then $V_t = W_t$.

The general equilibrium housing drag elasticity can then simply be computed from changes in money-metric consumption and observed changes in real income:

$$\mathcal{D}_t = 1 - \frac{d \log W_t}{d \log I_t}.$$

The general equilibrium elasticity may differ from the first-order elasticities reported in Table 1 if the response of housing expenditure shares to changes in income and relative prices generates quantitatively important higher-order terms, or if shifts in preference weights account for a substantial part of the evolution of housing expenditure shares.

Note that these computations did not require *any* assumptions on the production side of the economy. Intuitively, the structure of the production side influences prices and incomes but conditional on observing these outcomes, this

micro-structure is irrelevant.[9]

This changes if we want to decompose changes in income into its underlying determinants. In particular, we have to additionally use the housing market clearing equation to obtain housing supply at each point in time:

$$H_t = r_t^{-1} \phi_t I_t L_t \Rightarrow \bar{H}_t = H_t r_t^{-\kappa}$$

and then use housing supply to solve for the exogenous housing supply shifter $\bar{H}_t$ for each period. We also use the representative firm's first order condition to solve for the path of labor productivity:

$$A_t = I_t - r_t H_t (1+\kappa)^{-1} L_t^{-1}.$$

In addition, we solve for the full time path of $\Omega_{h,t}$ using the expression above, noting that the normalization pins $\Omega_{c,t} = \Omega_{h,t}^{-1}$, and use the observed data on the total number of households, L_t.

4. Housing Drag in the US Economy

In this section, we present estimates of the pass-through in the US economy between 1980 and 2020.

4.1 Aggregate Housing Drag, 1980–2020

Table 3 presents the housing drag in the US economy over the 1980 to 2020 period computed using our accounting framework from above. We show annualized income growth, money-metric welfare growth, and the exact general equilibrium housing drag elasticity as well as the first-order elasticity computed using the formula in Section 1. We present the numbers for our baseline model with non-homothetic preferences in Panel A. For comparison, Panel B shows the same numbers for a homothetic version of the model where we set $\epsilon = 1$ and then re-calibrate all fundamentals.

Panel A in Table 3 shows that for the baseline calibration the first order housing drag elasticity and its general equilibrium equivalent are virtually identical. One

[9] This is reminiscent of the results in Arkolakis, Costinot, and Rodríguez-Clare (2012), where the welfare gains from a change in trade costs can be computed from the change in the domestic trade share and the trade elasticity alone, holding technology and preferences fixed. We require incomes and prices in addition to shares since we are interested in measuring total welfare growth over time.

reason for this is that the inferred Ω_{ht} is practically constant over time, so that the first-order approximation is very good despite assuming that preference weights are constant. This highlights the excellent fit of the non-homothetic model to the aggregate data, the variation of income per capita explains almost all the change in the housing share without requiring large changes in preference weights.

A housing drag of 0.15 suggest that for every 1% of income growth, welfare only increases by 0.85%. This suggests that the housing sector exerts a significant downward pressure on aggregate real consumption in the US economy. If residential rents had grown at the same pace as other prices in the economy, the average American would be about 15% richer today. On an annualized basis, housing drag reduced the growth rate of real consumption growth from 1.38% to 1.18%.

TABLE 2: Housing Drag in General Equilibrium, 1980–2020

	Growth (%/yr)			
Version	Income	Welfare	$\mathcal{D}_t$	$\mathcal{D}_t^{\text{FO}}$
Panel A: Non-Homothetic Case ($\varepsilon = 0.75$)				
Baseline	1.38	1.18	0.15	0.15
A_t only	1.45	1.10	0.24	0.23
A_t + Z_t	1.38	1.18	0.15	0.15
Panel B: Homothetic Case ($\varepsilon = 1$)				
Baseline	1.38	1.04	0.24	0.15
A_t only	1.56	1.06	0.32	0.27
A_t + Z_t	1.49	1.15	0.23	0.20

Notes: The income and welfare columns report annualized growth rates of real income per capita and money-metric welfare between 1980 and 2020, expressed in percent. $\mathcal{D}_t$ is the general equilibrium housing drag elasticity computed as, $1 - \Delta \log W / \Delta \log I$. $\mathcal{D}_t^{\text{FO}}$ is the first-order approximation to the housing drag elasticity, computed as $\phi_{1980} \cdot \Delta \log r_{2020} / \Delta \log I_{2020}$. "Baseline" uses all inferred fundamentals. "A_t only" holds Z_t fixed at 1980 levels. "A_t + Z_t" additionally lets housing per-capita productivity vary.

Our structural model allows us to decompose the aggregate housing drag into its structural drivers. The second row in Panel A shows the housing drag for an economy in which only labor productivity grows as calibrated, the GE equivalent of Proposition 1. The third row adds in growth in housing productivity per capita.

The comparison of the income and welfare growth rates across the three rows is instructive. It shows that labor productivity growth contributed most income growth over the period. Adding in housing productivity growth and population growth in the third row lowers income growth as population doubles, so

that each individual owns a significantly smaller portion of land. At the same time, the increase in per-capita housing productivity growth is central to generate welfare increases: income growth alone is associated with large drag because housing is not expanding fast enough as the economy walks along the housing supply curve. The shift in the housing supply curve that is added in the third row is crucial to generating welfare growth, highlighting how powerful shifts in the housing supply curve are even if they lower rental revenue for individuals.

Shifting to the housing drag elasticities, remarkably, labor and housing productivity growth alone restore the baseline housing drag elasticity. This reflects that the only fundamental held fixed at its 1980 value in the third row is Ω_{ht} which is almost constant over time.

The implication of the three rows in Panel A is striking. It shows that all housing drag in the economy is due to supply side forces. In particular, no exogenous demand shocks captured by movement in Ω_{ht} explain housing drag. Instead, housing supply productivity, Z_t, has grown too slow to keep up with labor productivity growth in the economy, A_t. The housing supply curve has shifted out sufficiently to offset about half of the housing drag associated with productivity growth alone; but not enough to reduce it to zero.

Panel B shows that these conclusion hold broadly true in the homothetic version of the model. The key difference is that the homothetic model requires movement in Ω_{ht} to rationalize the time series of housing shares, given income and rent growth. As a result, there exists a gap between the first-order housing drag elasticity and GE elasticity. This highlights that the coincidence of first-order and GE housing drag elasticity in the non-homothetic is not by construction.

In the Appendix, we replicate the results in Table 3 in a large number of data sets for robustness.

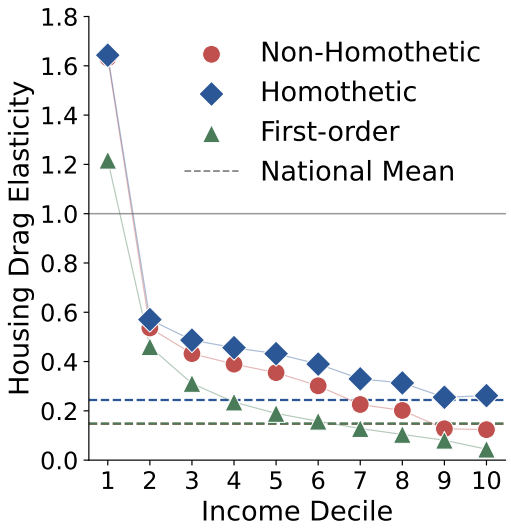
4.2 Housing Drag Throughout the Income Distribution

Table 3 showed averages for the entire US economy. Figure 1 suggest that the mean hides significant heterogeneity in housing drag across the income distribution. Intuitively, as the first order drag equation in 1 shows, what matters for housing drag is the income share of housing, income growth and rent growth. As is widely known, income growth differs widely across the income distribution with very little real wage growth since 1980 below the median (see, for example, Baum-Snow and Pavan, 2013).

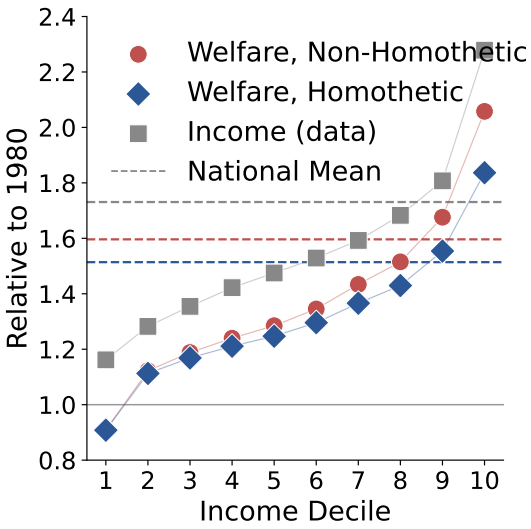
We use the US Decennial Census files and the American Community Survey to

FIGURE 2: Housing Drag and Welfare by Income Decile, 1980–2020

(A) Housing Drag Elasticity



(B) Welfare and Income Relative to 1980



Notes: This figure shows housing drag elasticities across deciles of the income distribution in the left panel, and welfare and income growth across deciles in the right panel. The underlying data uses national totals from the consumer expenditure survey and variation across deciles from the US Decennial Census and American Community Survey files.

construct average household income and housing shares out of income for each decile of the income distribution for each decade between 1980 and 2020. We then re-scale these data so that the national mean of household income and housing shares coincides exactly with those in the CEX. The data show that households in the poorest decile spend as much as 50-60% of their income on housing, while households in the top decile spend as little as 10%. Moreover the groups differ widely in terms of income growth relative to the non-housing CPI: incomes in the bottom decile have risen by 16% percent compared to 126% in the top decile. We assume all workers are exposed to the same rent price index.[10]

We then use our model framework to compute the GE housing drag and money metric welfare growth for each decile of the income distribution. To this end we infer a separate Ω_{ht} for each decile and decade, and the corresponding level of the utility index. Notably, we do not use the supply side part of our model, which would require more assumptions on how different worker types interact in the labor market.

Figure 2 presents the results. Panel A shows housing drag elasticity in general equilibrium for each decile both in the non-homothetic and homothetic version

[10]This is different from assuming they face the same rent in levels, all that matters is that their rent price growth is approximately similar.

of our model. In addition, the panel shows the first order housing drag elasticity from Section 1 applied separately for each decile. It also shows the national means from the baseline specification in Table 3 as horizontal lines. Panel B shows money-metric welfare relative to 1980 for each decile,and per-household income which is taken directly from the data.

Figure 2 shows that the national means in Table 3 are mostly driven by the highest-income deciles. The national housing drag elasticity is almost exactly that of households in the top two deciles. All other deciles are subject to much higher housing drag elasticities. The reason is that they experience less income growth, but spend a larger share of their income on housing and hence are more exposed to increases in the same rent price index. In other words, housing drag particularly hurts lower income households.

The differences across deciles are large. The housing drag elasticity for the median household is almost 0.5, so that almost half of the income growth gets eaten up by housing drag. The median household saw 50% income growth in terms of non-housing consumption since 1980, but only about 25% after accounting for the rise in residential rents, as shown in Panel B.

The lowest decile of households is hardest hit by the housing drag phenomenon. These households experienced almost no income growth in terms of non-housing consumption, yet spend about half of their income on housing. As a result, housing drag makes their welfare growth since 1980 turn negative. The housing drag elasticity is hence above 1, reflecting that the welfare loss per unit of income growth exceeds 1.

Notably, the difference in welfare estimates across the homothetic and non-homothetic specifications is less small for lower income deciles, since they experience little income growth so that the income elasticity of housing demand is less important. For the top deciles, the difference is more pronounced: their fast income growth allows the top decile households to lower their housing share in the non-homothetic specification making them even less exposed to housing drag then they already are.[11]

Figure 2 is a central finding of our paper. It shows that housing drag falls disproportionately on lower-income households, who spend more of their income on housing and have seen less income growth. One key determinant of both is ge-

[11] To be clear: the non-homothetic and homothetic numbers target the same data, so the underlying housing share is the same. However, in the non-homothetic case, the housing share of the top decile is in part rationalized through increases in their preference for housing, since without preference shifts the model would predict given their income growth their housing share should be even lower than in the data.

ography: rents, wages, and housing supply conditions vary dramatically across US cities, and a household's location shapes its exposure to the housing drag as much as its position in the income distribution. We therefore extend the model to a full spatial economy, which allows us to assess where housing drag is concentrated, how the spatial correlation between productivity growth and housing supply conditions shapes the aggregate, and what it implies for policy.

5. Spatial Heterogeneity

We now extend the model to a full spatial economy with 717 commuting zones, disaggregating the economy into local labor markets that differ in productivity, housing supply conditions, and amenities. This allows us to assess the spatial correlation between productivity growth and housing supply expansion highlighted by Hsieh and Moretti (2019), to characterize ex-post heterogeneity in housing drag across locations, and to evaluate the scope for spatially targeted policy.

5.1 Introducing Location Choices into the Model

Suppose now the economy consists of N local labor markets ("commuting zones") indexed by ℓ. Locations differ in their local labor productivity, A_ℓ, residential amenities, B_ℓ, and their housing supply elasticity, κ_ℓ. Each worker i receives a vector of idiosyncratic preference shocks, $\{\eta^i_\ell\}_\ell$ drawn from a Fréchet distribution with shape parameter θ.

We assume all locations produce the same homogeneous good and that trade in the consumption good across locations is free so that its price continues to serve as a convenient numeraire. Housing and labor markets clear within each location, so that there are location-specific wages and residential rents. In the Appendix, we generalize this model to have trade costs for the consumption good.

Workers within each location continue to have non-homothetic CES preferences as in equation 4 above. We assume the the existence of a *national* real estate investment trust (REIT) which owns all land in the economy and collects payments to it. Our baseline assumption is that every worker owns a share proportional to their labor income in the REIT. Total income then combines their labor income and the return to their fractional ownership of the REIT.

Workers choose their location ℓ to maximize their total utility which combines

their indirect consumption utility, local amenities, and their idiosyncratic preferences shocks. In particular, worker i's location choice is given by:

$$\ell_i^\star = \arg\max_\ell \{V_\ell B_\ell^{1/\theta} \eta_\ell^i\},$$

where V_ℓ is the indirect consumption utility of workers in location ℓ.

The properties of the Fréchet distribution imply a closed form expression for the number of workers choosing each location in equilibrium:

$$L_\ell = B_\ell V_\ell^\theta / \sum_\ell B_\ell V_\ell^\theta, \quad \text{where} \quad V_\ell = \Omega_{h,\ell}^{1/(1-\sigma)} (1-\phi_\ell)^{1/(1-\sigma)} I_\ell,$$

and $\Omega_{h,\ell}$ is a location-specific preference weight on housing.

5.2 Welfare in the Spatial Economy

In the spatial economy, agents are heterogeneous in their idiosyncratic location preferences, so defining social welfare requires an explicit aggregation choice. As a baseline, we adopt a utilitarian social welfare function of the form

$$V = \frac{1}{L} \int_i \eta_{\ell_i^\star}^i \, B_{\ell_i^\star}^{1/\theta} \, V_{\ell_i^\star} \, di.$$

V coincides with ex-ante expected indirect utility and admits the analytical expression

$$V^\theta = \sum_\ell B_\ell V_\ell^\theta.$$

The utilitarian welfare criterion has the advantage that our aggregate housing drag calculations carry seamlessly through to the spatial economy. In particular, the associated money metric W_t retains its interpretation as the uniform scaling of base-period incomes that delivers the same welfare as the post-shock economy at base-period rents, preferences, and amenities:

$$V_t^\theta = \sum_\ell B_{\ell 0} V_{\ell t}^\theta \quad \text{where} \quad \Omega_{h,\ell,0}^{-1} \, V_{\ell t}^{1-\sigma} + \Omega_{h,\ell,0} \, V_{\ell t}^{\varepsilon-\sigma} \, r_{\ell 0}^{1-\sigma} = W_t^{1-\sigma} I_{\ell 0}^{1-\sigma},$$

and the formula for the housing drag becomes:

$$\mathcal{D}_t = 1 - \frac{d \log W_t}{d \log I_t} \quad \text{where} \quad I_t = \frac{\sum_\ell \left[w_{\ell,t} L_{\ell,t} + r_{\ell,t} H_{\ell,t} / (1+\kappa_\ell) \right]}{L_t}.$$

A potential disadvantage of the utilitarian criterion is that it renders measurement dependent on the cardinalization of utility. This is because agents' sorting generically generates dispersion of marginal utility across locations, and different cardinalizations imply different profiles of marginal utility and hence potentially impact aggregate welfare estimates (see Donald et al., 2026). In Appendix A.2, we verify that our conclusions are robust to the aggregate productivity criterion of Baqaee and Burstein (2026), which avoids this issue by keeping agents on their base-period indifference curves through compensating transfers rather than aggregating cardinal utilities.

5.3 Data Construction for the Spatial Model

To extend our analysis to the spatial economy, we require the same four data points listed in Table 1 for the aggregate economy for every commuting zone and year combination. To construct such a data set, we turn to the US Decennial Census and the American Community Survey files from 1980, 1990, 2000, 2010, and 2019.

For each of these years, we construct commuting zone (see Tolbert and Sizer, 1996) identifiers in the data using the crosswalks from Autor and Dorn (2013). We construct household-level income and spending on rent. For owners, we impute rents based on the characteristics of their home using the sample of renters to fit a hedonic regression of log rents on home characteristics. We construct a rent price index by regressing log rents on housing characteristics and a commuting zone and year fixed effect. We interpret this location-year fixed effect as rent price index for observationally-equivalent units across regions and time.

Our final data set contains average household income per capita, the average housing share of income, the rent price index, and the total population for each commuting one and decade. We scale all regional variables so that they sum to the CEX totals. As a result our spatial panel aggregates exactly to the aggregate data we used above. Finally, we deflate all nominal variables by the non-housing CPI.

5.4 Housing Drag in Spatial Equilibrium

We begin by using the spatial dimension of our panel described in Section 3 to compute the aggregate housing drag in the spatial economy. As in the aggregate model, we impose $\Omega_{c,\ell}\Omega_{h,\ell} = 1$ for each location and normalize $\prod_\ell B_\ell = 1$. The only additional parameter required is the spatial labor supply elasticity θ which

we set to 5.1 using the estimates from Finlay and Williams (2025).

In the spatial extension, we infer fundamentals for each location using the same equations as in Section 3, including the recovery of $\Omega_{h,\ell,t}$ from location-level data on expenditure shares, incomes, and rents. In addition, we use the spatial labor equation to infer the amenity shifters from the observed location decisions of workers:

$$L_\ell = B_\ell V_\ell^\theta / \sum_\ell B_\ell V_\ell^\theta \Rightarrow B_\ell = L_\ell V_\ell^{-\theta} V^\theta.$$

Combining the normalization $\prod_\ell B_{\ell,t} = 1$ with the expression for amenities, aggregate indirect utility can be written as:

$$V_t = \left(\prod_\ell \frac{L_{\ell t}}{V_{\ell t}^\theta} \right)^{-\frac{1}{\theta N}} = \left(\prod_\ell \frac{L_{\ell t}}{\Omega_{h,\ell,t}^{\theta/(1-\sigma)} (1-\phi_{\ell t})^{\theta/(1-\sigma)} I_{\ell t}^\theta} \right)^{-\frac{1}{\theta N}}.$$

As before, we can thus compute the aggregate pass-through in the spatial economy without specifying the supply side.

TABLE 3: Housing Drag in General Equilibrium, 1980–2020

	Growth (%/yr)			
Version	Income	Welfare	$\mathcal{D}_t$	$\mathcal{D}_t^{\text{FO}}$
Panel A: Non-Homothetic Case ($\varepsilon = 0.75$)				
Baseline	1.38	1.02	0.26	0.15
$A_{\ell t}$ only	1.88	1.16	0.38	0.42
$A_{\ell t}$ + $Z_{\ell t}$	1.72	1.28	0.25	0.38
$A_{\ell t}$ + $Z_{\ell t}$ + $B_{\ell t}$	1.42	0.97	0.31	0.21
Panel B: Homothetic Case ($\varepsilon = 1$)				
Baseline	1.38	0.89	0.35	0.15
$A_{\ell t}$ only	1.95	1.10	0.43	0.42
$A_{\ell t}$ + $Z_{\ell t}$	1.78	1.24	0.30	0.37
$A_{\ell t}$ + $Z_{\ell t}$ + $B_{\ell t}$	1.51	0.97	0.35	0.25

Notes: The income and welfare columns report annualized growth rates of real income per capita and money-metric welfare between 1980 and 2020, expressed in percent. $\mathcal{D}_t$ is the general equilibrium housing drag elasticity computed as, $1 - \Delta \log W / \Delta \log I$. $\mathcal{D}_t^{\text{FO}}$ is the first-order approximation to the housing drag elasticity, computed as $\phi_{1980} \cdot \Delta \log r_{2020} / \Delta \log I_{2020}$. "Baseline" uses all inferred fundamentals. "$A_{\ell t}$ only" holds $\Omega_{h\ell t}$, $B_{\ell t}$, and $Z_{\ell t}$ fixed at 1980 levels. "$A_{\ell t}$ + $Z_{\ell t}$" additionally lets housing per-capita productivity vary. "$A_{\ell t}$ + $Z_{\ell t}$ + $B_{\ell t}$" additionally lets spatial amenities vary, holding only $\Omega_{h\ell t}$ fixed.

Table **??** presents the income and welfare growth as well as general equilibrium

and first-order housing drag elasticities for the spatial economy. The table is the direct spatial analogue to 3 above.

Disaggregating the economy into 717 commuting zones barely affects our conclusions about housing drag at the aggregate level. Labor productivity growth alone is associated with an aggregate housing drag of 0.34 which is higher than in the aggregate economy. Adding growth in housing productivity and population brings the economy almost back to baseline housing drag. This suggests that also in the spatial economy preference shocks play almost no role for aggregate housing drag.

Growth in local amenities can contribute to aggregate housing drag by being biased toward places with high- or low housing drag, thereby relocating population into those locations. However, Table **??** shows that this channel is negligible.

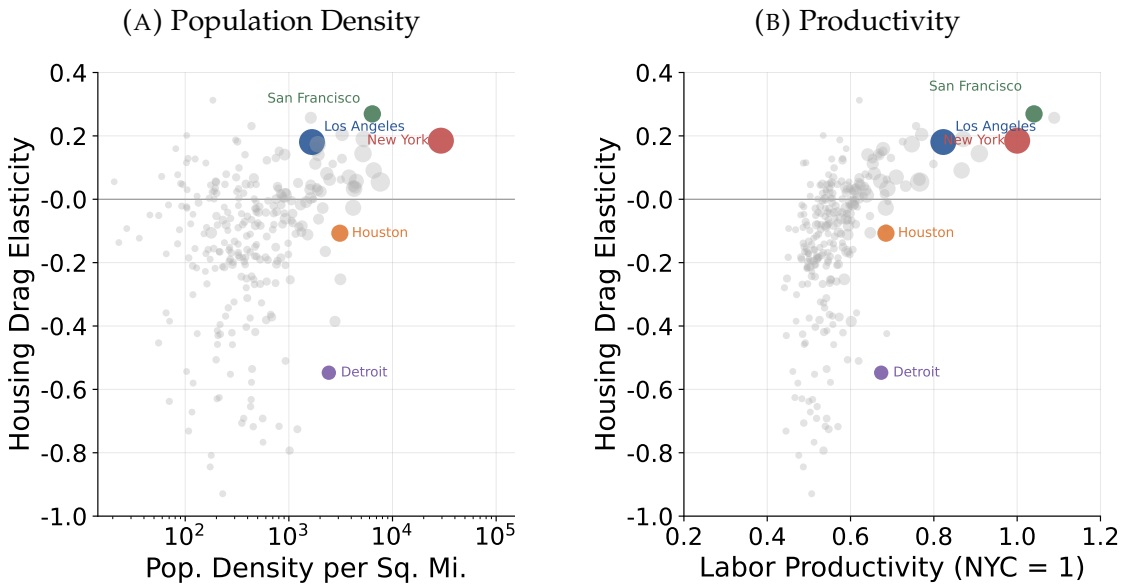
The aggregate housing drag elasticity hides dramatic variation in the elasticity across commuting zones. Figure 3 shows housing drag elasticities for the period between 1980 and 2020 for all US commuting zones. Panel A graphs the elasticity against commuting zone population density in 2020. Panel B shows how the elasticity varies with a commuting zones average labor productivity between 1980 and 2020, where we normalized the average labor productivity of New York City to 1. We color the ten largest commuting zones based on their 2020 population.

Among the ten largest cities, the ones with the highest housing drag elasticities are Los Angeles, San Francisco and New York, closely followed by Boston and Philadelphia. Chicago and Houston have housing drag elasticities of close to zero suggesting that labor productivity growth in these cities feeds into welfare growth almost one-for-one. Houston and Detroit even have negative housing drag elasticities: in these cities rents grew slower than non-housing consumption between 1980 and 2020.

Figure 3 shows that housing drag has little to do with population density or labor productivity. The ten largest cities also have the highest population density, yet their housing drag elasticity varies widely. Similarly, while the ten largest cities are among the most productive, there is little correlation of productivity with housing drag elasticities.

Next, we consider the determinants of the variation in housing drag elasticities across space. At the heart of housing drag lies a problem of an unbalanced expansion of the production possibility frontier: if labor productivity grows faster than the economy's ability to increase the supply of housing per capita, housing drag becomes important.

FIGURE 3: Housing Drag Elasticities Across Commuting Zones, 1980–2019



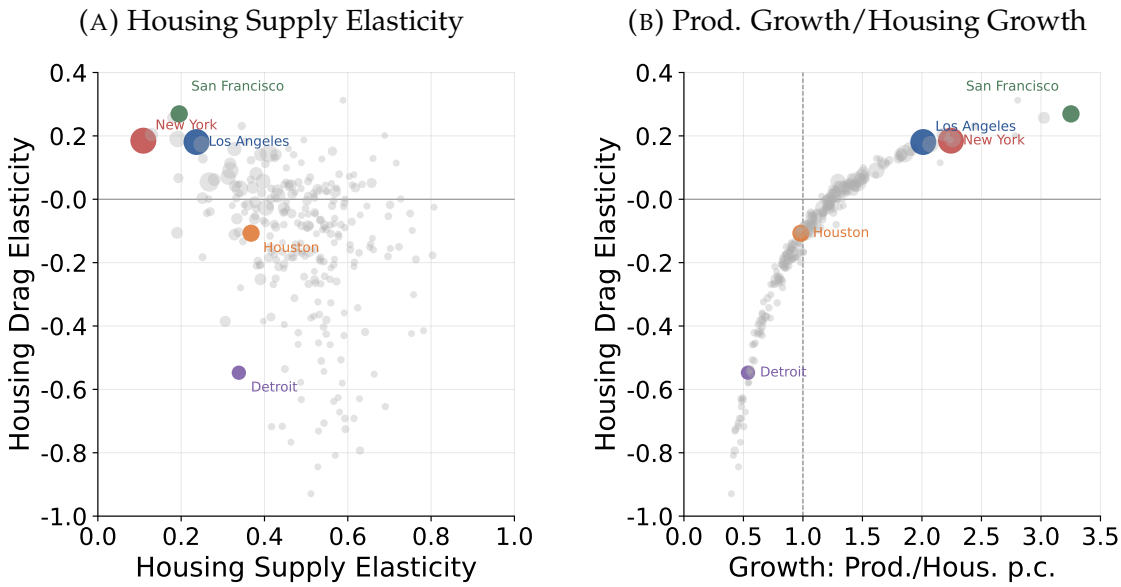
Notes: This figure shows housing drag elasticities across 717 US commuting zones. Panel graphs the housing drag elasticities against commuting zone population density, the right panel against average labor productivity over the 1980-2019 period. The underlying data uses national totals from the consumer expenditure survey and variation across deciles from the US Decennial Census and American Community Survey files.

Accordingly, Proposition 1 showed that the higher the housing supply elasticity the lower housing drag, reflecting that the housing supply elasticity measures the economy's ability to expand housing supply in response to demand growth. The left panel of Figure 4 relates the cross-sectional variation in housing drag elasticities to the variation in housing supply elasticities. The correlation between the two is effectively zero.

Panel A of Figure 4 shows that micro-housing elasticities are not predictive of a local economy's ability to pass productivity growth into welfare increases. This is reminiscent of a recent finding by Louie et al. (2025) that housing supply elasticities do not predict housing quantity growth across US metropolitan areas. This suggests that the housing drag elasticity is instead dominated by the other factors shown to influence it in Proposition 2.

Panel B of Figure 4 shows that the housing drag elasticity is tightly correlated with the relative growth rate of labor productivity and local growth in housing supply per capita. Cities that manage to shift out housing supply *per capita* in line with their productivity growth have low housing drag, whereas cities where the housing and non-housing sectors grow in an unbalanced way experience large housing drag.

FIGURE 4: Housing Drag Elasticities and Housing Supply, 1980–2020



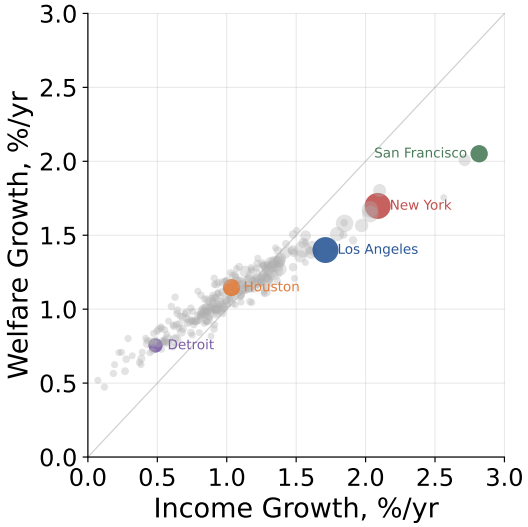
Notes: This figure shows housing drag elasticities across 717 US commuting zones. Panel graphs the housing drag elasticities against commuting zone housing supply elasticities from Baum-Snow and Han (2024), the right panel against the relative growth rate of labor productivity to housing supply per capita. The underlying data uses national totals from the consumer expenditure survey and variation across deciles from the US Decennial Census and American Community Survey files.

Together Panels A and B show that cities that manage to shift out their housing production possibility frontier in sync with their local labor productivity experience low housing drag. Differences in the slopes of the housing supply curves as measured by the housing supply elasticity are second order, to shifts in per-capita housing supply curves through changes in Z_t.

The housing drag elasticity is hence a summary measure of how unbalanced productivity growth is across the housing and non-housing sector. As Panel B shows it measures not just this: there is variation in the housing drag elasticity for every point on the x-axis. This reflects that the housing drag elasticity also captures changes in regional amenities and preferences for housing. The fact that the correlation in Panel B is so tight in turn reflects that spatial and sectoral preference shifters are not changing much between 1980 and 2020.

Finally, Figure 5 graphs annualized welfare growth against annualized labor productivity growth across commuting zones. The graph shows that many of the cities with the highest income growth are also those with the largest deviation from the 45-degree line, in other words they are cities with the highest housing drag. This reflects in part a self-reinforcing loop: local productivity growth raises incomes, attracting workers, which makes it even harder to raise housing supply

FIGURE 5: Annualized Income Growth vs. Welfare Growth, 1980–2019



Notes: This figure graphs income growth in terms of non-housing consumption against welfare growth between 1980 and 2019 for 717 US commuting zones. The underlying data uses national totals from the consumer expenditure survey and variation across deciles from the US Decennial Census and American Community Survey files.

per worker.

We emphasize that for income growth in a city like to New York to raise welfare, household would need to be able to rent larger quantities of housing at constant residential rents. Housing drag highlights a fundamental problem of fast-growing cities: they become victims of their own success, since over time more and more income growth is needed to raise welfare by the same amount. Figure 5 shows that many of the large American cities cannot raise housing supply fast enough to allow their inhabitants to fully benefit from local labor productivity growth.

Figure 5 raises the questions: what can be done to allow the US economy and its workers to benefit from the labor productivity growth it is already generating? We turn to this question in the next Section.

6. OPTIMAL SPATIAL POLICY

The previous sections established that housing drag absorbs a substantial fraction of U.S. income growth, and that this drag varies systematically across cities with local productivity and housing supply conditions. We now ask whether policy can raise the pass-through of income growth into welfare.

We consider two classes of intervention. The first is spatial redistribution through

location-specific income and housing production taxes. These instruments change the economy's position on its production possibility frontier, and may shift the frontier itself depending on the magnitude of spatial distortions at the initial equilibrium. The second intervention expands the effective housing supply, which shifts the frontier outward. We find that spatial distortions are quantitatively small, so redistribution yields negligible aggregate welfare gains, while housing supply expansion would have meaningfully raised welfare growth over the 1980–2020 period.

7. Conclusion

Housing is at once a basic necessity and the single largest component of the cost of living. This paper formalizes how constrained housing supply causes productivity-driven increases in purchasing power to translate into higher rents rather than larger consumption bundles, and measures that mechanism's quantitative importance through the lens of housing drag: the fraction of non-housing income growth that fails to pass through to money-metric welfare because housing becomes more expensive in equilibrium.

Applied to U.S. data from 1980 to 2020, the framework yields three findings. Between 1980 and 2020, aggregate housing drag was about 0.15: for every one percent increase in income, real consumption rose by just 0.85 percent. The drag is highly unequal, falling hardest on low-income households who devote larger budget shares to housing and have weaker scope to substitute away. And extending the analysis to the spatial economy yields a key insight: local housing supply elasticities have little bearing on housing drag. What matters is not the slope of local supply curves but shifts in housing productivity that move the entire supply curve outward. Movements along the production possibility frontier are second-order; movements of the frontier are first-order. This finding qualifies the interpretation of micro-level supply elasticity estimates central to the housing literature.

The policy implications follow directly. Reallocating households away from expensive, productive cities can reduce local rents, but at the cost of pushing workers from preferred locations, and the aggregate welfare gains are modest. Redistributive policies that change housing ownership or reallocate land between uses face the same limitation: they rearrange resources along the existing frontier without expanding it. Expanding the frontier itself, by raising floor-area ratios in high-productivity cities or accelerating housing-sector productivity, has first-order effects. Closing the drag over 1980 to 2020 would have required raising

housing quantity growth by roughly 0.3 percentage points per year and roughly doubling housing-sector productivity growth.

Housing drag is not primarily about spatial misallocation or regulatory barriers in any single city. It is about the aggregate failure of housing supply to keep pace with an economy whose productivity growth has been concentrated outside the housing sector. Whether the U.S. economy can continue to translate productivity growth into rising living standards increasingly depends on whether it can build housing fast enough.

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A. Theory Appendix

A.1 Proofs of Propositions

Setup. The representative household has non-homothetic CES (NHCES) preferences over housing services h and numeraire consumption c as in the main text. The equilibrium objects of interest are an indirect utility index V, a housing expenditure share ϕ, the rental price of housing services r, and real income per capita I (measured in the numeraire).

The household optimality conditions imply an *indirect utility* relation and a *housing share* relation:

$$\Omega_c V^{1-\sigma} + \Omega_h V^{\epsilon-\sigma} r^{1-\sigma} = I^{1-\sigma},$$
$$\frac{\phi}{1-\phi} = \frac{\Omega_h}{\Omega_c} V^{\epsilon-1} r^{1-\sigma}.$$

Following Redding and Weinstein (2020), we impose the normalization $\Omega_c \Omega_h = 1$. Hence

$$\Omega_c = \Omega_h^{-1}, \qquad \mathrm{d}\log \Omega_c = -\,\mathrm{d}\log \Omega_h.$$

Under this normalization, the two household relations become

$$\Omega_h^{-1} V^{1-\sigma} + \Omega_h V^{\epsilon-\sigma} r^{1-\sigma} = I^{1-\sigma}, \tag{8}$$
$$\frac{\phi}{1-\phi} = \Omega_h^2 V^{\epsilon-1} r^{1-\sigma}. \tag{9}$$

Housing supply is

$$H = \bar{H} r^{\kappa} \quad \Longrightarrow \quad \mathrm{d}\log H = \kappa\, \mathrm{d}\log r + \mathrm{d}\log \bar{H}. \tag{10}$$

Housing market clearing is

$$rH = \phi I L \quad \Longrightarrow \quad \mathrm{d}\log r + \mathrm{d}\log H = \mathrm{d}\log \phi + \mathrm{d}\log I + \mathrm{d}\log L. \tag{11}$$

Define money-metric welfare W as in the paper, and define the (instantaneous) *housing drag*

$$D \;\equiv\; 1 - \frac{d\log W}{d\log I}. \tag{12}$$

Proposition 4 (Housing Drag on Productivity-Driven Growth (Proposition 1))**.** *Consider a small shock to labor productivity that changes I and equilibrium rents r, holding $(\Omega_h, \bar{H}, L)$ fixed. Define*

$$\chi \equiv 1 + \frac{(1-\epsilon)(1-\phi)(1-\sigma)}{\sigma - 1 + \phi(1-\epsilon)} = 1 + \frac{(\epsilon-1)(1-\phi)(1-\sigma)}{(1-\sigma)+\phi(\epsilon-1)}. \tag{13}$$

Then the housing drag associated with productivity-driven growth is

$$D^A \equiv \phi \frac{\partial \log r / \partial \log A}{\partial \log I / \partial \log A} = \frac{\phi\,\chi}{\kappa + (1-\phi)\sigma + \phi\chi} \in (0,1). \tag{14}$$

Proof. **Step 1 (Solve for V as a function of (ϕ, I, Ω_h)).** Start from the normalized share condition (9):

$$\frac{\phi}{1-\phi} = \Omega_h^2 V^{\epsilon-1} r^{1-\sigma}.$$

Multiply both sides by $\Omega_h^{-1} V^{1-\sigma}$ to obtain

$$\Omega_h^{-1} V^{1-\sigma} \frac{\phi}{1-\phi} = \Omega_h^{-1} V^{1-\sigma}\, \Omega_h^2 V^{\epsilon-1} r^{1-\sigma} = \Omega_h V^{\epsilon-\sigma} r^{1-\sigma}.$$

Substitute this into (8):

$$\Omega_h^{-1} V^{1-\sigma} + \Omega_h V^{\epsilon-\sigma} r^{1-\sigma} = \Omega_h^{-1} V^{1-\sigma} \left(1 + \frac{\phi}{1-\phi}\right) = \Omega_h^{-1} V^{1-\sigma} \frac{1}{1-\phi} = I^{1-\sigma}.$$

Hence

$$V^{1-\sigma} = \Omega_h (1-\phi) I^{1-\sigma} \quad \Longrightarrow \quad V = \Omega_h^{\frac{1}{1-\sigma}} (1-\phi)^{\frac{1}{1-\sigma}} I. \tag{15}$$

Step 2 (Log-differentiate V holding Ω_h fixed). Take logs of (15) and totally differentiate:

$$\mathrm{d}\log V = \mathrm{d}\log I + \frac{1}{1-\sigma}\,\mathrm{d}\log \Omega_h + \frac{1}{1-\sigma}\,\mathrm{d}\log(1-\phi).$$

Under Proposition 1, $\mathrm{d}\log \Omega_h = 0$, and $\mathrm{d}\log(1-\phi) = -(\phi/(1-\phi))\,\mathrm{d}\log\phi$, so

$$\mathrm{d}\log V = \mathrm{d}\log I - \frac{\phi}{(1-\phi)(1-\sigma)}\,\mathrm{d}\log\phi. \tag{16}$$

Step 3 (Log-linearize the remaining equilibrium conditions). With $\mathrm{d}\log \bar{H} = 0$

and $\mathrm{d}\log L = 0$ in Proposition 1, (10)–(11) give

$$\mathrm{d}\log H = \kappa\ \mathrm{d}\log r, \tag{17}$$

$$(1+\kappa)\,\mathrm{d}\log r = \mathrm{d}\log\phi + \mathrm{d}\log I. \tag{18}$$

Next, log-differentiate (9). Since $\mathrm{d}\log\Omega_h = 0$ here,

$$d\log\left(\frac{\phi}{1-\phi}\right) = (\epsilon-1)\,\mathrm{d}\log V + (1-\sigma)\,\mathrm{d}\log r.$$

Using $d\log(\phi/(1-\phi)) = \frac{1}{1-\phi}\,\mathrm{d}\log\phi$, we get

$$\mathrm{d}\log\phi = (1-\phi)\big[(1-\sigma)\,\mathrm{d}\log r + (\epsilon-1)\,\mathrm{d}\log V\big]. \tag{19}$$

Step 4 (Solve for $\mathrm{d}\log r/\,\mathrm{d}\log I$). Substitute (16) into (19):

$$\mathrm{d}\log\phi = (1-\phi)\left[(1-\sigma)\,\mathrm{d}\log r + (\epsilon-1)\left(\mathrm{d}\log I - \frac{\phi}{(1-\phi)(1-\sigma)}\,\mathrm{d}\log\phi\right)\right].$$

Collect $\mathrm{d}\log\phi$ terms on the left:

$$\left(1+\frac{\phi(\epsilon-1)}{1-\sigma}\right)\mathrm{d}\log\phi = (1-\phi)\big[(1-\sigma)\,\mathrm{d}\log r + (\epsilon-1)\,\mathrm{d}\log I\big].$$

Define

$$D_0 \;\equiv\; (1-\sigma) + \phi(\epsilon-1). \tag{20}$$

Then $1+\frac{\phi(\epsilon-1)}{1-\sigma} = \frac{D_0}{1-\sigma}$, so

$$\mathrm{d}\log\phi = \frac{1-\phi}{D_0}\left[(1-\sigma)^2\ \mathrm{d}\log r + (1-\sigma)(\epsilon-1)\ \mathrm{d}\log I\right]. \tag{21}$$

Insert (21) into (18):

$$(1+\kappa)\,\mathrm{d}\log r = \frac{1-\phi}{D_0}\left[(1-\sigma)^2\ \mathrm{d}\log r + (1-\sigma)(\epsilon-1)\ \mathrm{d}\log I\right] + \mathrm{d}\log I.$$

Rearrange:

$$\left[(1+\kappa) - \frac{(1-\phi)(1-\sigma)^2}{D_0}\right]\mathrm{d}\log r = \left[1+\frac{(1-\phi)(\epsilon-1)(1-\sigma)}{D_0}\right]\mathrm{d}\log I.$$

Using (13), the right bracket equals χ. For the left bracket, write

$$\begin{aligned}\kappa+(1-\phi)\sigma+\phi\chi &= \kappa+(1-\phi)\sigma+\phi\left[1+\frac{(1-\phi)(\epsilon-1)(1-\sigma)}{D_0}\right]\\ &= 1+\kappa+(1-\phi)(\sigma-1)+\frac{\phi(1-\phi)(\epsilon-1)(1-\sigma)}{D_0}\\ &= 1+\kappa-(1-\phi)(1-\sigma)+\frac{\phi(1-\phi)(\epsilon-1)(1-\sigma)}{D_0}\\ &= 1+\kappa-(1-\phi)(1-\sigma)\left[1-\frac{\phi(\epsilon-1)}{D_0}\right]\\ &= 1+\kappa-(1-\phi)(1-\sigma)\left[\frac{1-\sigma}{D_0}\right] \;=\; (1+\kappa)-\frac{(1-\phi)(1-\sigma)^2}{D_0},\end{aligned}$$

where the penultimate step uses $D_0=(1-\sigma)+\phi(\epsilon-1)$. Therefore

$$\frac{\mathrm{d}\log r}{\mathrm{d}\log I}=\frac{\chi}{\kappa+(1-\phi)\sigma+\phi\chi}. \tag{22}$$

Step 5 (Convert rent pass-through to housing drag). With preference weights fixed, money-metric welfare changes satisfy

$$\mathrm{d}\log W=\;\mathrm{d}\log I-\phi\;\mathrm{d}\log r. \tag{23}$$

Hence

$$D=1-\frac{d\log W}{d\log I}=\phi\,\frac{\mathrm{d}\log r}{\mathrm{d}\log I}.$$

Under a productivity shock, $\mathrm{d}\log r/\,\mathrm{d}\log I$ equals (22), which implies (14). □

Proposition 5 (Generalized Housing Drag under $\Omega_c\Omega_h=1$ (Proposition 2)). *Allow small shocks to all fundamentals, so that $(\Omega_h,\bar{H},L,I)$ may all change. Define D^A and χ as in Proposition 1. Then the generalized housing drag satisfies*

$$D=D^A\left[1-\frac{1}{\chi}\frac{d\log(\bar{H}/L)}{d\log I}+\frac{1-\phi}{\chi}\,\frac{1-2\sigma+\epsilon}{(1-\sigma)+\phi(\epsilon-1)}\,\frac{d\log\Omega_h}{d\log I}\right]-\frac{1-2\phi}{1-\sigma}\,\frac{d\log\Omega_h}{d\log I}. \tag{24}$$

This expression depends on preference shifts only through Ω_h (since $\Omega_c=\Omega_h^{-1}$).

Proof. **Step 1 (Log-differentiate V allowing Ω_h to vary).** From (15),

$$\mathrm{d}\log V=\;\mathrm{d}\log I+\frac{1}{1-\sigma}\,\mathrm{d}\log\Omega_h+\frac{1}{1-\sigma}\,\mathrm{d}\log(1-\phi)=\;\mathrm{d}\log I+\frac{1}{1-\sigma}\,\mathrm{d}\log\Omega_h-\frac{\phi}{(1-\phi)(1-} \tag{25}$$

Step 2 (Log-linearize the share condition under $\Omega_c\Omega_h = 1$). Under the normalization, (9) implies

$$\log\left(\frac{\phi}{1-\phi}\right) = 2\log\Omega_h + (\epsilon-1)\log V + (1-\sigma)\log r.$$

Differentiating and using $d\log(\phi/(1-\phi)) = \frac{1}{1-\phi}\,\mathrm{d}\log\phi$ gives

$$\mathrm{d}\log\phi = (1-\phi)\big[(1-\sigma)\,\mathrm{d}\log r + (\epsilon-1)\,\mathrm{d}\log V + 2\,\mathrm{d}\log\Omega_h\big]. \tag{26}$$

Step 3 (Log-linearize supply and market clearing). From (10)–(11),

$$\mathrm{d}\log H = \kappa\,\mathrm{d}\log r + \mathrm{d}\log\bar{H}, \tag{27}$$

$$(1+\kappa)\,\mathrm{d}\log r = \mathrm{d}\log\phi + \mathrm{d}\log I - \mathrm{d}\log(\bar{H}/L). \tag{28}$$

Step 4 (Eliminate $\mathrm{d}\log V$ and solve for $\mathrm{d}\log\phi$). Substitute (25) into (26):

$$\mathrm{d}\log\phi = (1-\phi)\Big[(1-\sigma)\,\mathrm{d}\log r + (\epsilon-1)\Big(\mathrm{d}\log I + \frac{1}{1-\sigma}\,\mathrm{d}\log\Omega_h - \frac{\phi}{(1-\phi)(1-\sigma)}\,\mathrm{d}\log\phi\Big) + 2$$

Collect $\mathrm{d}\log\phi$ terms on the left exactly as in Proposition 1. Using D_0 from (20), this yields

$$\mathrm{d}\log\phi = \frac{1-\phi}{D_0}\Big[(1-\sigma)^2\,\mathrm{d}\log r + (1-\sigma)(\epsilon-1)\,\mathrm{d}\log I + (1-\sigma)\Big(2+\frac{\epsilon-1}{1-\sigma}\Big)\,\mathrm{d}\log\Omega_h\Big]. \tag{29}$$

Since

$$(1-\sigma)\Big(2+\frac{\epsilon-1}{1-\sigma}\Big) = 2(1-\sigma) + (\epsilon-1) = 1-2\sigma+\epsilon,$$

(29) becomes

$$\mathrm{d}\log\phi = \frac{1-\phi}{D_0}\Big[(1-\sigma)^2\,\mathrm{d}\log r + (1-\sigma)(\epsilon-1)\,\mathrm{d}\log I + (1-2\sigma+\epsilon)\,\mathrm{d}\log\Omega_h\Big]. \tag{30}$$

Step 5 (Solve for $\mathrm{d}\log r$). Insert (30) into (28):

$$(1+\kappa)\,\mathrm{d}\log r = \frac{1-\phi}{D_0}\Big[(1-\sigma)^2\,\mathrm{d}\log r + (1-\sigma)(\epsilon-1)\,\mathrm{d}\log I + (1-2\sigma+\epsilon)\,\mathrm{d}\log\Omega_h\Big] + \mathrm{d}\log I -$$

Rearranging gives

$$\mathrm{d}\log r = \frac{\chi\,\mathrm{d}\log I - \mathrm{d}\log(\bar{H}/L) + \frac{(1-\phi)(1-2\sigma+\epsilon)}{D_0}\,\mathrm{d}\log\Omega_h}{\kappa + (1-\phi)\sigma + \phi\chi}, \tag{31}$$

where χ is defined in (13). (When $\mathrm{d}\log(\bar{H}/L) = 0$ and $\mathrm{d}\log\Omega_h = 0$, (31) collapses to (22).)

Step 6 (Money-metric welfare change under $\Omega_c\Omega_h = 1$). The money-metric welfare differential (from totally differentiating the household expenditure function in the general case) is

$$\mathrm{d}\log W = \mathrm{d}\log I - \phi\,\mathrm{d}\log r - \frac{\phi}{1-\sigma}\,\mathrm{d}\log\Omega_h - \frac{1-\phi}{1-\sigma}\,\mathrm{d}\log\Omega_c. \tag{32}$$

Impose $\mathrm{d}\log\Omega_c = -\,\mathrm{d}\log\Omega_h$ to obtain

$$\mathrm{d}\log W = \mathrm{d}\log I - \phi\,\mathrm{d}\log r + \frac{1-2\phi}{1-\sigma}\,\mathrm{d}\log\Omega_h. \tag{33}$$

Divide by $\mathrm{d}\log I$ and use the definition (12):

$$D = \phi\,\frac{\mathrm{d}\log r}{\mathrm{d}\log I} - \frac{1-2\phi}{1-\sigma}\,\frac{\mathrm{d}\log\Omega_h}{\mathrm{d}\log I}. \tag{34}$$

Step 7 (Express $\phi\,\mathrm{d}\log r/\mathrm{d}\log I$ in terms of D^A). From (31), dividing through by $\mathrm{d}\log I$ gives

$$\phi\,\frac{\mathrm{d}\log r}{\mathrm{d}\log I} = \frac{\phi\chi}{\kappa + (1-\phi)\sigma + \phi\chi}\left[1 - \frac{1}{\chi}\frac{d\log(\bar{H}/L)}{d\log I} + \frac{1-\phi}{\chi}\frac{1-2\sigma+\epsilon}{D_0}\frac{d\log\Omega_h}{d\log I}\right].$$

Recognizing the leading fraction as D^A from (14) and substituting into (34) yields (5). □

Proof of Proposition 3

Proof. We use three identities implied by the equilibrium system. From housing-market clearing $r_t H_t = \phi_t I_t L_t$ and housing supply $H_t = \bar{H}_t r_t^{\kappa}$, taking logs and differentiating:

$$(1+\kappa)g_r(t) + g_{\bar{H}} = g_\phi(t) + g_I(t) + g_L. \tag{35}$$

From the expenditure share condition $\phi_t/(1-\phi_t) = (\Omega_{h,t}/\Omega_{c,t})V_t^{\epsilon-1}r_t^{1-\sigma}$:

$$\frac{d}{dt}\log\frac{\phi_t}{1-\phi_t} = g_{\Omega_h} - g_{\Omega_c} + (\epsilon-1)g_V(t) + (1-\sigma)g_r(t). \tag{36}$$

From the household conditions, indirect utility satisfies $V_t^{1-\sigma} = \Omega_{c,t}^{-1}(1-\phi_t)I_t^{1-\sigma}$. From housing-market clearing and the income identity $I_t = A_t + r_t H_t/[(1+$

$\kappa)L_t]$:

$$I_t = \frac{A_t}{1 - \phi_t/(1+\kappa)}. \tag{37}$$

Part (1). Consider a balanced-growth path with $\lim_{t\to\infty} \phi_t = \phi^* \in (0,1)$. Then $g_\phi(t) \to 0$ and $\frac{d}{dt}\log(\phi_t/(1-\phi_t)) \to 0$. From (37), $g_I(t) \to g_A$. From $V_t^{1-\sigma} = \Omega_{c,t}^{-1}(1-\phi_t)I_t^{1-\sigma}$:

$$g_V(t) \to g_A + \frac{1}{\sigma - 1} g_{\Omega_c}.$$

Taking limits in (35):

$$g_r \to g_r^{\text{int}} \equiv \frac{g_A + g_L - g_{\bar{H}}}{1+\kappa}.$$

Taking limits in (36) and collecting terms yields the necessary condition $\Delta = 0$ as defined in (7).

Part (2). Suppose $\Delta > 0$ and $\lim_{t\to\infty} \phi_t = \phi^* \in (0,1)$. Part (1) then forces $\Delta = 0$, a contradiction. If instead $\phi_t \to 0$, then $\log(\phi_t/(1-\phi_t)) \to -\infty$, contradicting (36) since $\Delta > 0$ ensures the drift is eventually positive. Hence $\phi_t \to 1$.

It remains to compute the limiting drag $\mathcal{D}_t = \phi_t\, g_r(t)/g_I(t) + \frac{\phi_t g_{\Omega_h}}{(1-\sigma)g_I(t)} + \frac{(1-\phi_t)g_{\Omega_c}}{(1-\sigma)g_I(t)}$ along a path with $\phi_t \to 1$. We distinguish two cases.

Case $\kappa = 0$. Housing supply is fixed at $H_t = \bar{H}_t$, so the income identity reduces to $(1-\phi_t)I_t = A_t$. As $\phi_t \to 1$:

$$g_I(t) = g_A + \frac{\dot{\phi}_t}{1-\phi_t} \to \infty.$$

From housing-market clearing $r_t \bar{H}_t = \phi_t I_t L_t$:

$$g_r(t) = g_\phi(t) + g_I(t) + g_L - g_{\bar{H}}.$$

Since $g_\phi, g_L, g_{\bar{H}}$ are finite while $g_I \to \infty$, we have $g_r(t)/g_I(t) \to 1$, and all terms in 1 involving finite growth rates divided by $g_I(t)$ vanish. Hence $\mathcal{D}_t \to 1$.

Case $\kappa > 0$. The income identity (37) gives $I_t = A_t/(1-\phi_t/(1+\kappa))$. As $\phi_t \to 1$, the denominator converges to $\kappa/(1+\kappa) > 0$, so $g_I(t) \to g_A$. Since $\phi_t \to 1$ implies $g_\phi(t) \to 0$, equation (35) gives:

$$g_r(t) \to \frac{g_A + g_L - g_{\bar{H}}}{1+\kappa}.$$

The money-metric welfare growth rate satisfies $g_W = g_I - \phi\, g_r - \frac{\phi}{1-\sigma} g_{\Omega_h} - \frac{1-\phi}{1-\sigma} g_{\Omega_c}$.

At $\phi = 1$ and $g_I = g_A$:

$$\lim_{t\to\infty} \mathcal{D}_t = \frac{g_A + g_L - g_{\bar{H}}}{(1+\kappa)g_A} + \frac{g_{\Omega_h}}{(1-\sigma)g_A} = \frac{1}{1+\kappa}\left(1 + \frac{g_L - g_{\bar{H}}}{g_A}\right) + \frac{g_{\Omega_h}}{(1-\sigma)g_A}.$$

□

A.2 Aggregate Productivity

Our baseline money-metric welfare measure requires no information on the supply side; therefore, it is identified directly from data on incomes, rents, and expenditure shares. This appendix considers an alternative criterion proposed by Baqaee and Burstein (2026) (henceforth BB) that requires knowledge of structural fundamentals but avoids a well-known limitation of the utilitarian approach to measuring welfare, namely that the utilitarian aggregate is not invariant to monotone transformations of individual utility functions. The aggregate productivity criterion $\mathcal{A}(t)$ sidesteps this by working with compensated allocations. It asks how much total factor productivity could be uniformly reduced while still allowing every agent to be made at least as well off as at the base period, given appropriate lump-sum transfers. It is defined in terms of revealed preference, respects the Pareto criterion, and is unaffected by redistributions that move the economy along the Pareto frontier.

A.2.1 Definition

At time t, fundamentals are $\{A_\ell(t), \bar{H}_\ell(t), B_\ell(t), \Omega_{h,\ell}(t)\}_\ell$, with $\Omega_{c,\ell}(t) = \Omega_{h,\ell}(t)^{-1}$ under our normalization. Let $t = 0$ be the base period with decentralized utilities $\{U_{i,0}\}_i$.

Definition. *Aggregate productivity $\mathcal{A}(t)$ is*

$$\mathcal{A}_t = \max \left\{ Z^{-1} : \exists \text{ compensated equilibrium with } U_i^c \geq U_{i,0} \ \forall i \right\}, \tag{38}$$

where the compensated equilibrium scales both primary factors by $\mathcal{A}(t)$ (labor productivity to $A_\ell/\mathcal{A}$ and housing productivity to $\bar{H}_\ell/\mathcal{A}$), assigns each agent i to the location that minimizes the transfer needed to restore their base-period utility,

$$\ell_i^c = \arg\min_\ell T_{i\ell}, \qquad T_{i\ell} = e\left(r_\ell^c,\, \Omega_{h,\ell},\, \frac{U_{i,0}}{B_\ell^{1/\theta}\eta_{i\ell}}\right) - I_\ell^c, \tag{39}$$

where $e(\cdot)$ is the NHCES expenditure function, and satisfies housing market clearing, $\int_{i:\ell_i^c=\ell} \phi_{\ell,i}^c E_{\ell,i}^c \, di = (r_\ell^c)^{1+\kappa_\ell} \bar{H}_\ell/\mathcal{A}$, and budget neutrality, $\int_i T_{i,\ell_i^c} \, di = 0$.

If $\mathcal{A}(t) = 1.05$, all primary factor productivities could be reduced by 5% and, via lump-sum transfers, every agent could still be made at least as well off as at $t = 0$.

A.2.2 Characterization

To characterize aggregate productivity, we establish the following result.

Proposition 6 (Aggregate Productivity). *With $t = 0$ denoting the base period, $\lambda_\ell \equiv I_\ell L_\ell / Y$ and $s_\ell \equiv A_\ell/(\mathcal{A} I_\ell)$, where $Y = \sum_{\ell'} I_{\ell'} L_{\ell'}$, aggregate productivity $\mathcal{A}(t)$ solves the differential equation (40) with boundary conditions (41) and evolution equations (42)–(50).*

$$d\ln \mathcal{A}(s) = \sum_\ell \lambda_\ell^c(s)\Big\{ s_\ell^c(s)\, d\ln A_\ell(s) + \tfrac{\phi_\ell^c(s)}{1+\kappa_\ell}\, d\ln \tfrac{\bar H_\ell(s)}{L(s)} + \tfrac{d\ln B_\ell(s)}{\theta \gamma_\ell^{V,I}(s)} + \tfrac{1-2\phi_\ell^c(s)}{1-\sigma}\, d\ln \Omega_{h,\ell}(s)\Big\} \tag{40}$$

where superscript c denotes evaluation along the compensated path and $\gamma_\ell^{V,I} = \frac{1-\sigma}{1-\sigma+(\epsilon-1)\phi_\ell^c}$, with boundary conditions

$$\lambda_\ell^c(0) = \lambda_\ell(0), \quad \phi_\ell^c(0) = \phi_\ell(0), \quad s_\ell^c(0) = s_\ell(0). \tag{41}$$

Along the compensated path the shares evolve as

$$d\ln \phi_\ell^c = \gamma_\ell^{V,I}(1-\phi_\ell^c)\big[(\epsilon-1)\, d\ln V_\ell^c + (1-\sigma)\, d\ln r_\ell^c + 2\, d\ln \Omega_{h,\ell}\big], \tag{42}$$

$$d\ln \gamma_\ell^{V,I} = -\gamma_\ell^{V,I}\phi_\ell^c\big(\tfrac{\epsilon-1}{1-\sigma}\big)\, d\ln \phi_\ell^c, \tag{43}$$

$$d\ln s_\ell^c = d\ln \tfrac{A_\ell}{\mathcal{A}} - d\ln I_\ell^c, \tag{44}$$

$$d\ln \lambda_\ell^c = d\ln\big(L_\ell^c I_\ell^c\big) - \textstyle\sum_k \lambda_k^c\, d\ln\big(L_k^c I_k^c\big), \tag{45}$$

$$d\ln r_\ell^c = \tfrac{1}{1+\kappa_\ell}\big[d\ln \phi_\ell^c + d\ln I_\ell^c + d\ln L_\ell^c - d\ln \tfrac{\bar H_\ell}{\mathcal{A}}\big], \tag{46}$$

$$d\ln I_\ell^c = s_\ell^c\, d\ln \tfrac{A_\ell}{\mathcal{A}} + (1-s_\ell^c)\, d\ln \mathrm{REIT}^c, \tag{47}$$

$$d\ln \mathrm{REIT}^c = \frac{\sum_\ell \frac{r_\ell^c H_\ell^c}{1+\kappa_\ell}\big[(1+\kappa_\ell)\, d\ln r_\ell^c + d\ln \frac{\bar H_\ell}{L^c \mathcal{A}}\big]}{\sum_\ell \frac{r_\ell^c H_\ell^c}{1+\kappa_\ell}}, \tag{48}$$

$$d\ln V_\ell^c = \gamma_\ell^{V,I}\big[d\ln I_\ell^c - \phi_\ell^c\, d\ln r_\ell^c + \tfrac{1-2\phi_\ell^c}{1-\sigma}\, d\ln \Omega_{h,\ell}\big], \tag{49}$$

$$\begin{aligned} d\ln \tfrac{L_\ell^c}{L} = {} & \textstyle\sum_k \eta_{\ell k}^{L,I}\, d\ln \tfrac{I_k^c}{\mathcal{A}} + \sum_k \eta_{\ell k}^{L,r}\, d\ln r_k^c \\ & + \textstyle\sum_k \eta_{\ell k}^{L,B}\, d\ln B_k + \sum_k \eta_{\ell k}^{L,\Omega_h}\, d\ln \Omega_{h,k}, \end{aligned} \tag{50}$$

where the Jacobians $\eta_{\ell k}^{L,x}(s) \equiv \partial \ln L_\ell^c(s)/\partial \ln x_k(s)$ are evaluated in the compensated equilibrium at s and are implied by the compensated choice rule (39).

Equation (40) involves the same four fundamentals as our baseline pass-through formula, weighted by compensated income shares λ_ℓ^c. At $s = 0$, by the first welfare theorem, the compensated and decentralized equilibria coincide, so the two formulas are identical to a first order. Note also that $\sum_\ell \lambda_\ell s_\ell + \sum_\ell \lambda_\ell \frac{\phi_\ell}{1+\kappa_\ell} = 1$ (labor plus land income equals GDP), while $s_\ell + \frac{\phi_\ell}{1+\kappa_\ell} \neq 1$ at any individual location because REIT income is redistributed nationally.

A.2.3 Implementation

To implement Proposition 6, we linearly interpolate fundamentals between $t = 0$ and $t = 1$ into S sub-steps and numerically integrate the differential system using Euler steps with Monte Carlo evaluation of the compensated choice Jacobian.

Initialization. Draw $M = 500$k agents with shocks $\eta_{i\ell} \sim$ Fréchet$(1, \theta)$. Compute base-period utilities $U_{i,0} = \max_\ell \eta_{i\ell} B_\ell(0)^{1/\theta} V_\ell(0)$. Initialize the compensated state at the decentralized equilibrium: $\lambda_\ell^c(0) = \lambda_\ell(0)$, $\phi_\ell^c(0) = \phi_\ell(0)$, $s_\ell^c(0) = s_\ell(0)$, $\mathcal{A}(0) = 1$.

At each sub-step $s \to s + \Delta s$:

1. Compute $d \ln \mathcal{A}$ from (40).
2. Initialize $d \ln L_\ell^c = 0$ and iterate, setting $x_\ell(s + \Delta s) = x_\ell(s) \cdot e^{d \ln x_\ell}$:
   (a) Given $d \ln L_\ell^c$, solve (49)–(48) analytically for $(d \ln r_\ell^c, d \ln I_\ell^c, d \ln V_\ell^c, d \ln \phi_\ell^c)$. The system is linear conditional on $d \ln L_\ell^c$, so we substitute to obtain a scalar equation for $d \ln \text{REIT}^c$ and back out all other variables.
   (b) Evaluate compensated location choice via Monte Carlo: for each agent i and location ℓ, compute the transfer
   $$T_{i\ell} = e\big(r_\ell(s+\Delta s),\, \Omega_{h,\ell}(s+\Delta s),\, U_{i,0}/(B_\ell(s+\Delta s)^{1/\theta}\eta_{i\ell})\big) - I_\ell(s+\Delta s)$$
   using the NHCES expenditure function, then set $\ell_i^c = \arg\min_\ell T_{i\ell}$. The compensated population is $L_\ell^{c,\text{new}} = (\text{count}_\ell / M) \cdot L$, ensuring $\sum_\ell L_\ell^{c,\text{new}} = L$.
   (c) Compute $d \ln L_\ell^{c,\text{new}} = \ln L_\ell^{c,\text{new}} / L_\ell^c(s)$. Update: $d \ln L_\ell^c \leftarrow \alpha\, d \ln L_\ell^{c,\text{new}} + (1 - \alpha)\, d \ln L_\ell^c$. Repeat until convergence.
3. Update $(\lambda_\ell^c, s_\ell^c, \phi_\ell^c, \gamma_\ell^{V,I})$ per (42)–(45).

TABLE 4: Aggregate-Productivity Drag in the Spatial Economy (1980–2020)

		Growth Rate (%/yr)		
Income	Source	Income	Agg. Prod.	Drag
Panel A: Homothetic Case ($\varepsilon = 1$)				
Mean	CEX	1.38	1.06	0.23
Mean	NIPA	1.81	1.41	0.22
Median	CPS	0.61	0.34	0.44
Panel B: Non-Homothetic Case ($\varepsilon = 0.75$)				
Mean	CEX	1.38	1.14	0.17
Mean	NIPA	1.81	1.62	0.11
Median	CPS	0.61	0.36	0.40

Notes: Income and Agg. Prod. report annualised growth rates of real income per capita and aggregate productivity between 1980 and 2020, computed as $(X_{2020}/X_{1980})^{1/40} - 1$ and expressed in percent. Drag is the fraction of income growth not passed through to aggregate productivity, $1 - \Delta \log \mathcal{A} / \Delta \log I$.

TABLE 5: Decomposition of Aggregate-Productivity Drag in the U.S. Economy (1980–2020)

		Drag		Marginal Contrib.		
Income	Source	Baseline	A_t only	Z_t, L_t	$\Omega_{h\ell t}$	$B_{\ell t}$
Panel A: Homothetic Case ($\varepsilon = 1$)						
Mean	CEX	0.23	0.28	-0.14	0.06	0.02
Mean	NIPA	0.22	0.18	-0.08	0.09	0.03
Median	CPS	0.44	0.28	-0.02	0.13	0.05
Panel B: Non-Homothetic Case ($\varepsilon = 0.75$)						
Mean	CEX	0.17	0.30	-0.16	0.00	0.03
Mean	NIPA	0.11	0.19	-0.10	-0.02	0.04
Median	CPS	0.40	0.29	-0.02	0.06	0.08

Notes: Drag is $1 - \Delta \log \mathcal{A} / \Delta \log I$ over 1980–2020, where $\mathcal{A}$ is aggregate productivity. "Baseline" uses all inferred fundamentals. "A_t only" holds Ω_{ht}, B_{ht}, Z_t, and L_t fixed at 1980. Marginal contributions report the average change in drag from activating each group across all coalitions of the remaining groups.

A.2.4 Results

Tables 4 and 5 report the aggregate-productivity counterparts of Table **??**. The two welfare criteria deliver nearly identical baseline drag estimates. Comparing Panel A of Table 4 Table **??**, the aggregate-productivity criterion implies drag of 0.23 (CEX mean), 0.22 (NIPA mean), and 0.44 (CPS median) over 1980–2020, within one to two percentage points of the utilitarian estimates of 0.24, 0.22, and 0.45. Panel B shows that the non-homothetic case is equally close: 0.17 vs. 0.15 for CEX mean, 0.11 vs. 0.09 for NIPA mean, and 0.40 vs. 0.41 for CPS median. This near-equivalence is expected: the two criteria coincide to a first order at the initial equilibrium, and the second-order differences from compensated location resorting are empirically small.

The decomposition in Table 5 tells a broadly similar story to Table **??**. Housing supply and population shifts (Z_t, L_t) again reduce drag relative to the productivity-only counterfactual, and labor productivity remains the dominant source of housing demand pressure. Two quantitative differences stand out. First, the productivity-only counterfactual in Panel A of Table 5 generates less drag under the aggregate-productivity criterion than under the utilitarian one in Table **??** (0.28 vs. 0.42 for CEX mean income), reflecting the fact that compensated allocations hold agents on base-period indifference curves rather than aggregating cardinal utilities. Second, preference shifts ($\Omega_{h\ell t}$) and amenity changes ($B_{\ell t}$) contribute modestly to drag in Panel A of Table 5 (0.06 and 0.02 respectively for CEX mean income), whereas they are negligible in the corresponding column of Table **??**.

The near-equivalence of the utilitarian and aggregate-productivity drag estimates also sharpens the interpretation of Section **??**. By construction, $\mathcal{A}(t)$ is redistribution-neutral: spatial taxes and transfers move the economy along the Pareto frontier without affecting it, so they cannot raise aggregate productivity. The fact that estimated housing drag is nearly identical under $\mathcal{W}$ and $\mathcal{A}$ therefore implies that the negligible welfare gain from optimal spatial redistribution is not an artifact of the utilitarian criterion. Donald et al. (2026) show that, under optimal spatial transfers, the technology term alone drives aggregate welfare, so the scope for redistribution to improve on the market outcome is determined by the spatial dispersion of marginal utility. In our model, this dispersion is attenuated by REIT income: high rents in productive cities raise housing costs for local residents, but raise dividend income for all households proportionally. This compression of real income differences across space narrows the marginal utility gap that optimal transfers would otherwise exploit, leaving little room for redistribution to improve aggregate welfare.

A.2.5 Proof of Proposition 6

Proof. For each i, define the expenditure and indirect utility functions:

$$e_i\left(\frac{\boldsymbol{A}}{\mathcal{A}}, \frac{\bar{\boldsymbol{H}}/L}{\mathcal{A}}, \boldsymbol{r}, \boldsymbol{B}, \boldsymbol{\Omega}_h, U_i^0\right)$$
$$= \min_{T_i} \; T_i + \mu_i \left[\max_{\ell} \left\{\eta_\ell^i B_\ell^{1/\theta} \Omega_{h,\ell}^{1/(1-\sigma)} (I_\ell + T_i)(1-\phi_{\ell,i})^{1/(1-\sigma)}\right\} - U_{i,0}\right],$$

$$v_i = \max_{\ell} \eta_\ell^i B_\ell^{1/\theta} \Omega_{h,\ell}^{1/(1-\sigma)} (I_\ell + T_i)(1-\phi_{\ell,i})^{1/(1-\sigma)}$$

where $\mathcal{A}$ is pinned down by the feasibility constraint $\int e_i \, di = 0$. By the first-order condition of the expenditure minimization, $-\mu_i \frac{\partial v_i}{\partial T_i} = 1$ at the optimum. The derivative of indirect utility with respect to the transfer is:

$$\frac{\partial v_i}{\partial T_i} = \eta_{\ell^*(i)}^i B_{\ell^*(i)}^{1/\theta} \Omega_{h,\ell^*(i)}^{1/(1-\sigma)} (1-\phi_{\ell^*(i)})^{1/(1-\sigma)} \cdot \gamma_{\ell^*(i)}^{V,I},$$

where the factor $\gamma_\ell^{V,I}$ accounts for the NHCES feedback. Therefore:

$$-\mu_i = \frac{1}{\gamma_{\ell^*(i)}^{V,I} \, \eta_{\ell^*(i)}^i \, B_{\ell^*(i)}^{1/\theta} \, \Omega_{h,\ell^*(i)}^{1/(1-\sigma)} \, (1-\phi_{\ell^*(i)})^{1/(1-\sigma)}} \tag{51}$$

We use the envelope theorem to compute each partial derivative of e_i, using $\partial e_i / \partial x = \mu_i \, \partial v_i / \partial x$ for parameters x that enter through the agent's indirect utility at the chosen location $\ell^*(i)$. Intuitively, higher productivity lowers the transfer needed.

$$\frac{\partial e_i}{\partial (A_\ell / \mathcal{A})} = \mu_i \cdot \frac{\partial v_i}{\partial I_\ell} = \mu_i \cdot \frac{v_i}{(1/\gamma_\ell^{V,I})(I_\ell + T_i)} = -1 \cdot \mathbf{1}[\ell^*(i) = \ell].$$

The derivative with respect to $\bar{H}_\ell/(L\mathcal{A})$ enters through $\text{REIT} = \sum_{\ell'} \frac{r_{\ell'}^{1+\kappa_{\ell'}} \bar{H}_{\ell'}}{(1+\kappa_{\ell'}) L \mathcal{A}}$. Since REIT income enters every agent's $I_{\ell'}$ identically, and $\partial e_i / \partial I = -1$:

$$\frac{\partial e_i}{\partial (\bar{H}_\ell / (L\mathcal{A}))} = -\frac{r_\ell^{1+\kappa_\ell}}{1+\kappa_\ell}.$$

The derivative with respect to r_ℓ reflects two channels. First, it increases REIT income for all agents:

$$\int \left.\frac{\partial e_i}{\partial \ln r_\ell}\right|_{\text{REIT}} di = -L \cdot \frac{r_\ell H_\ell}{L} = -r_\ell H_\ell.$$

For an agent residing in location ℓ, holding income fixed, $d \ln r_\ell$ raises ϕ_ℓ which lowers $(1-\phi)^{1/(1-\sigma)}$:

$$\left.\frac{\partial e_i}{\partial \ln r_\ell}\right|_{\text{housing}} = \mu_i \cdot \left(-\frac{\phi_\ell v_i}{1/\gamma_\ell^{V,I}}\right) \cdot \mathbf{1}[\ell^*(i)=\ell] = \phi_\ell (I_\ell + T_i) \cdot \mathbf{1}[\ell^*(i)=\ell],$$

Integrated over agents in ℓ:

$$\int \left.\frac{\partial e_i}{\partial \ln r_\ell}\right|_{\text{housing}} di = \phi_\ell I_\ell L_\ell = r_\ell H_\ell.$$

Therefore the total rent derivative vanishes:

$$\int \frac{\partial e_i}{\partial \ln r_\ell}\, di = -r_\ell H_\ell + r_\ell H_\ell = 0. \tag{52}$$

This envelope result reflects that the decentralized economy is ex-ante Pareto efficient. As a result, rent changes have no impact first-order welfare impact. Equivalently, the marginal housing cost to residents equals the marginal REIT benefit to all agents.

Next, for the preference shifter $\Omega_{h,\ell}$. Under the normalization $\Omega_{c,\ell} = \Omega_{h,\ell}^{-1}$, increasing $\Omega_{h,\ell}$ simultaneously decreases $\Omega_{c,\ell}$, so the envelope derivative combines both effects. Following the same logic as the proof of Proposition 2, the combined effect on agent i's expenditure at the chosen location $\ell^*(i) = \ell$ is:

$$\left.\frac{\partial e_i}{\partial \ln \Omega_{h,\ell}}\right|_{\Omega_c \Omega_h = 1} = -\frac{1-2\phi_\ell}{1-\sigma}(I_\ell + T_i) \cdot \mathbf{1}[\ell^*(i)=\ell].$$

For amenities:

$$\frac{\partial e_i}{\partial \ln B_\ell} = \mu_i \cdot \frac{v_i}{\theta} \cdot \mathbf{1}[\ell^*(i)=\ell] = -\frac{(I_\ell + T_i)}{\theta \gamma_\ell^{V,I}} \cdot \mathbf{1}[\ell^*(i)=\ell]$$

Now, differentiate the condition $\int e_i\, di = 0$ to obtain:

$$\begin{aligned} 0 = &-\sum_\ell s_\ell I_\ell L_\ell \, d \ln \frac{A_\ell}{\mathcal{A}} - \sum_\ell \frac{r_\ell H_\ell}{1+\kappa_\ell} \, d \ln \frac{\bar{H}_\ell}{L\mathcal{A}} \\ &+ 0 \cdot d \ln r_\ell \\ &- \sum_\ell \int_{i:\ell=\ell^*(i)} \frac{1}{\theta \gamma_\ell^{V,I}} (I_\ell + e_i)\, di \, d \ln B_\ell \\ &- \sum_\ell \frac{(1-2\phi_\ell)\, I_\ell L_\ell}{1-\sigma} \, d \ln \Omega_{h,\ell}. \end{aligned}$$

Here we used: $\int \mathbf{1}[\ell^*(i) = \ell] \cdot (A_\ell / \mathcal{A})\, di = s_\ell I_\ell L_\ell$; $r_\ell H_\ell = \int_{i:\ell^*(i)=\ell} \phi_{\ell,i}\,(I_\ell + T_i)\, di$; and (52), to eliminate the rent terms. Denoting

$$Y \equiv \sum_\ell s_\ell I_\ell L_\ell + \sum_\ell \frac{r_\ell H_\ell}{1+\kappa_\ell},$$

and collecting the $d \ln \mathcal{A}$ terms on the left we then obtain (40). Since the first Welfare Theorem holds, $\log \mathcal{A}(0) = 0$, so the observed equilibrium coincides with the compensated equilibrium, where $e_i = 0$ for all i.

To obtain the evolution equations for $(\phi^c_\ell, s^c_\ell, \lambda^c_\ell)$ and the remaining objects along the compensated path, log-differentiate: (i) the within-location demand system, yielding (42) and (49); (ii) housing market clearing, yielding (46); (iii) income accounting with REIT redistribution, yielding (47)–(48); and (iv) the definitions of s^c_ℓ and λ^c_ℓ, yielding (44)–(45). The evolution of the compensated population distribution enters through (50), which is the log-linear representation of the compensated choice rule (39); its Jacobians are evaluated at the compensated equilibrium and can be obtained by differentiating the transfer-minimization problem (analytically where possible, or numerically via finite differences) at each s. □

A.3 Optimal Policy Derivations

Planner's problem. The planner maximizes

$$W = \left(\sum_{\ell} B_{\ell} V_{\ell}^{\theta} \right)^{1/\theta}$$

subject to the spatial equilibrium conditions

$$V_{\ell} = \Omega_{h,\ell}^{1/(1-\sigma)} (1 - \phi_{\ell})^{1/(1-\sigma)} I_{\ell}^{d}, \tag{53}$$

$$\frac{\phi_{\ell}}{1 - \phi_{\ell}} = \Omega_{h,\ell}^{2} V_{\ell}^{\varepsilon - 1} r_{\ell}^{1-\sigma}, \tag{54}$$

$$r_{\ell} H_{\ell} = \phi_{\ell} \, I_{\ell}^{d} \, L_{\ell}, \quad H_{\ell} = \bar{H}_{\ell} \left[(1 - \tau_{\ell}^{H}) \, r_{\ell} \right]^{\kappa_{\ell}}, \tag{55}$$

$$L_{\ell} = \frac{B_{\ell} V_{\ell}^{\theta}}{\sum_{k} B_{k} V_{k}^{\theta}} \, \bar{L}, \tag{56}$$

where $I_{\ell}^{d} \equiv (1 - \tau_{\ell}^{I}) I_{\ell} + T$, $I_{\ell} = A_{\ell} + \text{REIT}/\bar{L}$, $\text{REIT} = \sum_{k} (1 - \tau_{k}^{H}) r_{k} H_{k} / (1 + \kappa_{k})$, and $T = \left[\sum_{k} \tau_{k}^{I} L_{k} I_{k} + \sum_{k} \tau_{k}^{H} r_{k} H_{k} \right] / \bar{L}$.

From the welfare aggregator and (56), $\partial \ln W / \partial \ln V_{\ell} = L_{\ell} / \bar{L}$. For any instrument τ_{ℓ}, add and subtract $(L_{\ell}/\bar{L}) \, \partial \ln V_{\ell} / \partial \tau_{\ell}$:

$$\frac{\partial \ln W}{\partial \tau_{\ell}} = \left(1 - \frac{L_{\ell}}{\bar{L}} \right) \frac{\partial \ln V_{\ell}}{\partial \tau_{\ell}} + \frac{\partial \ln W}{\partial \tau_{\ell}}.$$

Setting the left-hand side to zero eliminates the second term, giving

$$0 = \left(1 - \frac{L_{\ell}}{\bar{L}} \right) \frac{\partial \ln V_{\ell}}{\partial \tau_{\ell}} + \frac{\mu}{W} \frac{\partial B}{\partial \tau_{\ell}}, \tag{57}$$

where $\mu \equiv \partial W / \partial T$ is the welfare value of a unit increase in T and $B \equiv \sum_{k} \tau_{k}^{I} L_{k} I_{k} + \sum_{k} \tau_{k}^{H} r_{k} H_{k}$. Cross-location welfare effects of REIT feedbacks are absorbed into $\partial \ln W / \partial \tau_{\ell} = 0$. REIT does affect $\partial B / \partial \tau_{\ell}$ through the response of the existing tax base. Since $I_{k} = A_{k} + \text{REIT}/\bar{L}$ and $r_{k} H_{k} = \phi_{k} I_{k}^{d} L_{k}$:

$$\frac{\partial B}{\partial \, \text{REIT}} = \bar{\tau} \equiv \bar{\tau}^{I} + \bar{\tau}_{R}^{H}, \quad \bar{\tau}^{I} \equiv \frac{\sum_{k} \tau_{k}^{I} L_{k}}{\bar{L}}, \quad \bar{\tau}_{R}^{H} \equiv \frac{\sum_{k} \tau_{k}^{H} \phi_{k} L_{k} \xi_{k}}{\bar{L}}, \tag{58}$$

where $\xi_{k} \equiv \partial \ln (r_{k} H_{k}) / \partial \ln I_{k}^{d} \big|_{\text{REIT}}$ is the elasticity of rental expenditure to disposable income at fixed REIT. Differentiating $r_{\ell} H_{\ell} = \phi_{\ell} I_{\ell}^{d} L_{\ell}$ at fixed REIT and

using $\partial\phi_\ell/\partial \ln I_\ell^d = -(1-\sigma)(1-\phi_\ell)(\Psi_\ell - 1)$ (derived below):

$$\xi_\ell = -(1-\sigma)\frac{(1-\phi_\ell)(\Psi_\ell - 1)}{\phi_\ell} + 1 + \theta\Psi_\ell. \tag{59}$$

The REIT multiplier $\zeta \equiv \sum_k (1-\tau_k^H)\phi_k L_k \xi_k/[(1+\kappa_k)\bar{L}]$ captures the general equilibrium amplification of any shock to REIT. From the rental expenditure elasticity $\eta_\ell \equiv \partial \ln(r_\ell H_\ell)/\partial \ln \bar{H}_\ell$ derived below:

$$\phi_\ell \xi_\ell = -\eta_\ell \Psi_\ell (1+\kappa_\ell), \tag{60}$$

so defining $\bar{\lambda}^H \equiv \bar{\tau}/(1-\zeta)$, the tax-base correction is

$$\Gamma_\ell \equiv 1 + (1-\tau_\ell^H)\eta_\ell \Psi_\ell \bar{\lambda}^H = 1 - \frac{(1-\tau_\ell^H)(1+\kappa_\ell)\left[1+\phi_\ell \frac{\varepsilon-1}{1-\sigma}\right]}{\kappa_\ell + \sigma(1-\phi_\ell)}\bar{\lambda}^H, \tag{61}$$

where the second equality substitutes the closed form for $\eta_\ell \Psi_\ell$ derived below.

Income tax FOC. At fixed T and REIT, $\partial \ln V_\ell/\partial \tau_\ell^I = -\Psi_\ell I_\ell / I_\ell^d$. By the REIT multiplier, $\partial \,\text{REIT}/\partial \tau_\ell^I = -(1-\tau_\ell^H)\phi_\ell L_\ell \xi_\ell I_\ell/[(1-\zeta)(1+\kappa_\ell)]$, so using (60):

$$\frac{\partial B}{\partial \tau_\ell^I} = L_\ell I_\ell + (1-\tau_\ell^H)\eta_\ell \Psi_\ell \bar{\lambda}^H L_\ell I_\ell = L_\ell I_\ell \Gamma_\ell.$$

Substituting into (57) and canceling I_ℓ gives the income tax FOC in the main text with $\bar{\lambda}^I \equiv \mu/W$.

Housing production tax FOC. At fixed T and REIT, $\partial \ln V_\ell/\partial \tau_\ell^H = -[\kappa_\ell/(1-\tau_\ell^H)]\,\partial \ln V_\ell/\partial \ln \bar{H}_\ell$. Using $\partial \ln(r_\ell H_\ell)/\partial \tau_\ell^H\big|_{\text{REIT}} = -\eta_\ell \kappa_\ell/(1-\tau_\ell^H)$ and the REIT multiplier:

$$\frac{\partial B}{\partial \tau_\ell^H} = \phi_\ell I_\ell^d L_\ell \left(1 - \frac{\tau_\ell^H \eta_\ell \kappa_\ell}{1-\tau_\ell^H}\right)\left[1 - \frac{(1-\tau_\ell^H)\bar{\lambda}^H}{1+\kappa_\ell}\right].$$

Substituting into (57) and using $\partial \ln V_\ell/\partial \ln \bar{H}_\ell = [\phi_\ell/(\kappa_\ell + \sigma(1-\phi_\ell))]\Psi_\ell$ (derived below), then canceling $\phi_\ell L_\ell/\bar{L}$:

$$\frac{\kappa_\ell \Psi_\ell}{\kappa_\ell + \sigma(1-\phi_\ell)} = \frac{\mu I_\ell^d}{W} \cdot \frac{1 - L_\ell/\bar{L}}{L_\ell/\bar{L}}\left(1 - \frac{\tau_\ell^H \eta_\ell \kappa_\ell}{1-\tau_\ell^H}\right)\left[1 - \frac{(1-\tau_\ell^H)\bar{\lambda}^H}{1+\kappa_\ell}\right]. \tag{62}$$

From the income tax FOC, $(\mu/W)(I_\ell^d)(1-L_\ell/\bar{L})/(L_\ell/\bar{L}) = \Psi_\ell/\Gamma_\ell$. Substituting and canceling Ψ_ℓ:

$$\frac{\kappa_\ell}{\kappa_\ell + \sigma(1-\phi_\ell)} = \frac{1}{\Gamma_\ell}\left(1 - \frac{\tau_\ell^H \eta_\ell \kappa_\ell}{1-\tau_\ell^H}\right)\left[1 - \frac{(1-\tau_\ell^H)\bar{\lambda}^H}{1+\kappa_\ell}\right]. \tag{63}$$

Substituting the closed form $\eta_\ell = -[(1+\kappa_\ell)((1-\sigma)+\phi_\ell(\varepsilon-1))]/[(1-\sigma)(\kappa_\ell + \sigma(1-\phi_\ell))\Psi_\ell]$ and multiplying through by $[\kappa_\ell+\sigma(1-\phi_\ell)]\Gamma_\ell[1-(1-\tau_\ell^H)\bar{\lambda}^H/(1+\kappa_\ell)]^{-1}/\kappa_\ell$ gives the housing production tax FOC in the main text.

Characterization of Ψ_ℓ. Differentiating (53) at fixed $\Omega_{h,\ell}$ and T:

$$\Psi_\ell = -\frac{1}{(1-\sigma)(1-\phi_\ell)}\frac{\partial \phi_\ell}{\partial \ln I_\ell^d} + 1. \tag{64}$$

Log-differentiating (54):

$$\frac{\partial \phi_\ell}{\partial \ln I_\ell^d} = \phi_\ell(1-\phi_\ell)\left[(\varepsilon-1)\Psi_\ell + (1-\sigma)\frac{\partial \ln r_\ell}{\partial \ln I_\ell^d}\right]. \tag{65}$$

Differentiating $r_\ell H_\ell = \phi_\ell I_\ell^d L_\ell$ at fixed REIT:

$$(1+\kappa_\ell)\frac{\partial \ln r_\ell}{\partial \ln I_\ell^d} = \frac{1}{\phi_\ell}\frac{\partial \phi_\ell}{\partial \ln I_\ell^d} + 1 + \theta\Psi_\ell. \tag{66}$$

Setting $p \equiv \partial\phi_\ell/\partial \ln I_\ell^d$, (64) gives $p = -(1-\sigma)(1-\phi_\ell)(\Psi_\ell - 1)$. Substituting into (65) and (66) and solving:

$$\Psi_\ell = \frac{(1-\sigma)[\kappa_\ell + \sigma(1-\phi_\ell)]}{(1-\sigma)[\kappa_\ell + \sigma + \phi_\ell(1-\sigma+\theta)] + \phi_\ell(\varepsilon-1)(1+\kappa_\ell)}, \tag{67}$$

which after inverting gives the main text expression for Ψ_ℓ.

Characterization of $\partial \ln V_\ell/\partial \ln \bar{H}_\ell$ and η_ℓ. At fixed I_ℓ^d, differentiating (53):

$$\frac{\partial \ln V_\ell}{\partial \ln \bar{H}_\ell} = -\frac{1}{(1-\sigma)(1-\phi_\ell)}\frac{\partial \phi_\ell}{\partial \ln \bar{H}_\ell}.$$

The analogous system to (65)–(66) at fixed I_ℓ^d gives $\partial\phi_\ell/\partial \ln \bar{H}_\ell = -(1-\sigma)(1-\phi_\ell)v$ where $v \equiv \partial \ln V_\ell/\partial \ln \bar{H}_\ell$, and the housing market clearing condition picks up a direct supply shift:

$$(1+\kappa_\ell)\frac{\partial \ln r_\ell}{\partial \ln \bar{H}_\ell} = \frac{1}{\phi_\ell}\frac{\partial \phi_\ell}{\partial \ln \bar{H}_\ell} + \theta v - 1.$$

Solving gives $v = \phi_\ell(1-\sigma)/D_\ell$ where D_ℓ is the same denominator as in (67). Dividing by (67):

$$\frac{\partial \ln V_\ell}{\partial \ln \bar{H}_\ell} = \frac{\phi_\ell}{\kappa_\ell + \sigma(1-\phi_\ell)} \Psi_\ell. \tag{68}$$

For η_ℓ, from the housing market clearing differentiation at fixed I_ℓ^d:

$$\frac{\partial \ln(r_\ell H_\ell)}{\partial \ln \bar{H}_\ell} = \left[\theta - \frac{(1-\sigma)(1-\phi_\ell)}{\phi_\ell}\right] v - 1.$$

Substituting v and simplifying:

$$\eta_\ell = -\frac{(1+\kappa_\ell)[(1-\sigma) + \phi_\ell(\varepsilon - 1)]}{(1-\sigma)[\kappa_\ell + \sigma(1-\phi_\ell)]} \cdot \frac{1}{\Psi_\ell}. \tag{69}$$

Multiplying by Ψ_ℓ confirms (60): $\eta_\ell \Psi_\ell = -\phi_\ell \xi_\ell / (1+\kappa_\ell)$.

A.4 Extension: Introducing Trade Costs

The main part of the paper assumed the existence of a freely-traded numeraire good and hence the absence of trade costs. In this section, we introduce a version of the model with trade costs.

The Framework We assume each region produces its own idiosyncratic Armington variety. The indirect utility function then becomes:

$$V_\ell^{1-\sigma} P_\ell^{1-\sigma} + V_\ell^{\epsilon-\sigma} \Omega_\ell r_\ell^{1-\sigma} = I_\ell^{1-\sigma} \tag{70}$$

where the price index for the consumption good now varies across locations ℓ because of the presence of trade costs. It is defined by:

$$P_\ell^{1-\eta} = \sum_k \tau_{k\ell}^{1-\eta} p_{k\ell}^{1-\eta} \tag{71}$$

where $\{\tau_{k\ell}\}_{k\ell}$ denotes the matrix of trade costs which is such that $\tau_{k\ell} = 1$ for all $k = \ell$ and $\tau_{k\ell} > 1$ for all $k \neq \ell$.

The housing share of expenditure in each location is then given by:

$$\varphi_\ell = \frac{\Omega_\ell V_\ell^{\epsilon-1} r_\ell^{1-\sigma}}{P_\ell^{1-\sigma} + \Omega_\ell V_\ell^{\epsilon-1} r_\ell^{1-\sigma}}. \tag{72}$$

The housing supply function changes somewhat since the housing sector now uses land and the tradable bundle:

$$H_\ell = \bar{H}_\ell \, r_\ell^{\kappa} \, P_\ell^{-\frac{\kappa_2}{1+\kappa}} \tag{73}$$

Housing market clearing in each location:

$$r_\ell H_\ell = \varphi_\ell I_\ell L_\ell \tag{74}$$

The additional equilibrium condition is labor market clearing:

$$w_\ell L_\ell = \sum_k \pi_{\ell k} (1 - \varphi_k) I_k L_k \tag{75}$$

Finally income

$$I_\ell = w_\ell + \varphi_\ell \, \text{REIT} = A_\ell (1 + \zeta) \tag{76}$$

so that

$$\zeta(\text{REIT}, Y) = \frac{\sum_k r_k H_k/(1+\kappa)}{\sum_k A_\ell L_\ell} := \frac{\text{REIT}}{Y}. \tag{77}$$

And lastly, a spatial labor supply module:

$$L_\ell = \frac{B_\ell V_\ell^\theta}{\sum_\ell B_\ell V_\ell^\theta} \tag{78}$$

Notice that the model in the main body is nested as a special case when $\tau_{k\ell} = 1$ for all k and ℓ and $\eta \to \infty$ so that regional varieties are perfect substitutes.

How to Quantify It

Step 1: Solve for prices, price indices, and trade matrices. Guess the vector of factory-gate prices of each regional variety, $\{p_\ell\}_\ell$. Use this to construct the price index

$$P_\ell^{1-\eta} = \sum_k \tau_{k\ell}^{1-\eta} p_k^{1-\eta} \tag{79}$$

and the trade shares $\pi_{i\ell} = \tau_{i\ell}^{1-\eta} p_i^{1-\eta} / P_\ell^{1-\eta}$. Compute the implied total payroll in each location using the market clearing equation and data:

$$w_\ell L_\ell = \sum_k \pi_{\ell k}(1-\varphi_k) I_k L_k \tag{80}$$

Increase prices in locations in which implied payroll is higher than in the data and vice versa. Iterate until convergence.

Step 2: Solve for the preference weights in housing. Solve for the preference weight in terms of indirect utility:

$$\Omega_\ell = \frac{\varphi_\ell}{1-\varphi_\ell} \frac{P_\ell^{1-\sigma}}{V_\ell^{\epsilon-1} r_\ell^{1-\sigma}} \tag{81}$$

where indirect utility is pinned down by plugging the housing share into the indirect utility equation:

$$V_\ell = P_\ell^{-1}(1-\varphi_\ell)^{\frac{1}{1-\sigma}} I_\ell \tag{82}$$

Using this we can solve for Ω_ℓ implied by the data.

Step 3: Infer the housing stock. As before:

$$H_\ell = r_\ell^{-1} \varphi_\ell I_\ell L_\ell \tag{83}$$

Step 4: Infer productivity. Guess ζ and solve for wages as $w_\ell = I_\ell/(1+\zeta)$. Update ζ using

$$\zeta = \frac{\sum_k r_k H_k/(1+\kappa_k)}{\sum_k w_k L_k} \tag{84}$$

and iterate until convergence. Once converged, compute productivity as $A_\ell = w_\ell / p_\ell$.

Step 5: Infer spatial amenities. As before:

$$B_\ell = \frac{L_\ell}{V_\ell^\theta} \Big/ \sum_\ell \frac{L_\ell}{V_\ell^\theta} \tag{85}$$

Solving the Model and Computing Drag The solution algorithm has two nested loops: an outer loop over population and an inner loop over wages and rents.

Outer loop: population. Guess the population of each location, L_ℓ. Given L_ℓ, solve the inner loop described below to obtain equilibrium wages, rents, and utility. Then update population using

$$L_\ell = \frac{B_\ell V_\ell^\theta}{\sum_\ell B_\ell V_\ell^\theta} \tag{86}$$

and iterate until convergence.

Inner loop: wages and prices. Given population L_ℓ, guess wages w_ℓ and proceed as follows. Compute prices and trade shares:

$$p_\ell = \frac{w_\ell}{A_\ell} \tag{87}$$

$$P_\ell^{1-\eta} = \sum_k \tau_{k\ell}^{1-\eta} p_k^{1-\eta} \tag{88}$$

$$\pi_{i\ell} = \frac{\tau_{i\ell}^{1-\eta} p_i^{1-\eta}}{P_\ell^{1-\eta}} \tag{89}$$

Rents sub-loop. Guess rents r_ℓ in each location. Compute the REIT share:

$$\zeta = \frac{\sum_k r_k H_k/(1+\kappa_k)}{\sum_k w_k L_k} \tag{90}$$

and total income $I_\ell = w_\ell(1+\zeta)$. Solve for indirect utility in each location:

$$V_\ell^{1-\sigma} P_\ell^{1-\sigma} + V_\ell^{\epsilon-\sigma} \Omega_\ell r_\ell^{1-\sigma} = I_\ell^{1-\sigma} \tag{91}$$

Compute expenditure shares on housing:

$$\varphi_\ell = \frac{\Omega_\ell V_\ell^{\epsilon-1} r_\ell^{1-\sigma}}{P_\ell^{1-\sigma} + \Omega_\ell V_\ell^{\epsilon-1} r_\ell^{1-\sigma}} \tag{92}$$

Update rents using the housing market clearing condition and iterate until convergence.

Once rents have converged, update wages using

$$w_\ell = L_\ell^{-1} \sum_k \pi_{\ell k} (1-\varphi_k) I_k L_k \tag{93}$$

and iterate the wage loop until convergence.

Once wages have converged, update population using

$$L_\ell = \frac{B_\ell V_\ell^\theta}{\sum_\ell B_\ell V_\ell^\theta} \tag{94}$$

and iterate the outer loop until convergence.