Should cities be denser? Land rent capture and the disutility of densification *

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Abstract

Urban densification generates substantial agglomeration benefits but also raises land rents, whose distribution may affect the social value of density. We show that when land rents are only partially captured and some accrue to absentee owners, density entails a previously overlooked resource leakage that can counteract agglomeration forces. We incorporate partial land rent capture into a monocentric city model and a quantitative model of Berlin. In both, the optimal policy combines agglomeration subsidies with taxes on floor space proportional to uncaptured rents. Quantitatively, this leakage can substantially reduce optimal density and materially alter the welfare gains from conventional densification policies.

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1 Introduction

There is a broad consensus that urban densification provides several social, economic, and environmental benefits through agglomeration economies. As reviewed by Duranton and Puga (2020), denser cities make firms and workers more productive by facilitating knowledge spillovers, better matching between employers and employees, and greater sharing of infrastructure, specialized suppliers, and labor pools. Density also stimulates innovation, increases the variety and accessibility of goods and services, reduces average travel distances, and supports more energy-efficient buildings and transportation systems. Furthermore, dense urban environments foster richer consumption amenities and cultural opportunities while reducing per-capita greenhouse gas emissions and energy use. Overall, these productivity, accessibility, and innovation gains constitute the primary economic rationale for encouraging urban density.

On the other hand, the same forces that make density attractive also generate substantial costs. Developers must rely on increasingly expensive high-rise construction technologies, households consume less living space or relocate farther from employment centers, and transport infrastructure becomes more congested. In addition, greater density may increase crowding, reduce green space, increase exposure to local pollution despite lower emissions per capita, and heighten vulnerability to infectious diseases and pandemics.

Duranton and Puga (2020) therefore characterize urban density as involving a fundamental trade-off: agglomeration economies generate large productivity and accessibility gains, but beyond some point the marginal costs of crowding, congestion, and increasingly costly urban adaptation outweigh these benefits. Because many of these benefits and costs are externalities, market outcomes do not necessarily produce socially optimal levels of urban density. Empirically, however, positive agglomeration externalities usually seem to offset negative ones (see, e.g., Ooi and Le, 2013; Zahirovich-Herbert and Gibler, 2014; Ahlfeldt et al., 2015; Ahlfeldt and Pietrostefani, 2019), which may explain the general consensus towards densification policies in practice. Upzoning reforms, height-limit relaxations, and density subsidies are advocated on the grounds that housing-supply constraints and unpriced agglomeration externalities make the market city too sparse (e.g., Hsieh and Moretti, 2019; Glaeser and Gyourko, 2018; Duranton and Puga, 2023; Baum-Snow, 2023; Anagol et al., 2026).

However, higher density also generates another effect: higher land prices. Density is produced on land, so the same forces that make a location valuable make its owner rich. Duranton and Puga (2020) argue that higher land prices are not themselves a social cost, since they mainly reflect the increased value of scarce urban land and represent transfers rather than actual resource losses. Dismissing land rents as mere transfers, however, rests on an implicit assumption: that these rents stay in the economy. When land is owned by absentee landlords and its rents are only partly taxed and redistributed to city residents, the competition for central locations transfers resources out of the city, implying that part of the rents that density creates is lost. We show in this paper that this leakage of resources constitutes an economic force that opposes densification in welfare terms, and that has not been quantified previously. We abstract from the costs of density discussed above to isolate this channel, which operates even without them. We also show in two different urban models that this counter-densification force can overcome positive net agglomeration economies, and, therefore, cities may be optimally less dense than the literature so far suggests.

What makes this finding relevant is that both partial capture and absentee ownership are the norm rather than the exception. Land rent capture is typically partial: property taxes, the main instrument through which cities recover land rents, represent on average around 5% of total tax revenues for OECD countries (OECD, 2022). Absentee ownership is, in turn, large: non-resident buyers account for around 16.5% of property transactions in Paris (Cvijanović and Spaenjers, 2021), out-of-town buyers for 10% of purchases in Manhattan (Favilukis and Van Nieuwerburgh, 2021), and in 2022 Canada's federal government passed an act banning foreign purchases of residential property to tackle the issue.

We develop a framework in which a share between zero and one of the land rents returns to residents and the rest leaves with absentee landlords. The two extremes are the most common assumptions in the literature. A share of zero is the untaxed absentee landlord: as pointed out by Redding and Rossi-Hansberg (2017), there is a long tradition in urban economics of abstracting from land rents by postulating the existence of absentee landlords who receive all the rents but are not explicitly modeled (see, e.g., Ahlfeldt et al., 2015; Brinkman, 2016; Schmutz-Bloch and Sidibé, 2024). A share of one is full land rent capture, as under collective ownership, an assumption that is more prevalent in the literature on optimal place-based policies (see, e.g., Fajgelbaum and Gaubert, 2020; Li et al., 2024).[1] Intermediate values stand for imperfect land rent capture through taxation or partial resident ownership.

Our measure of welfare is residents' utility, as is most common in quantitative spatial models. Because of this, capturing more rents and redistributing them is trivially welfare-improving. We treat the share of captured land rents as a primitive of the economy, not an instrument, under the assumption that it cannot be easily changed and, when it changes, it does so by small amounts. Because the share is hard to measure and is different for different cities, we characterize the optimal combination of spatial taxes and subsidies that balances agglomeration economies and this opposing force, at every value the share can take rather than at a point estimate. The share extends a formulation that Papageorgiou and Pines (1999) introduced in the theory of the monocentric city.

We introduce partial land rent capture and redistribution into two benchmark urban models.

[1] Full capture is also the assumption behind the Henry George theorem, under which a confiscatory tax on land rents finances the local public sector (Flatters et al., 1974; Arnott and Stiglitz, 1979).

The first is the monocentric city, where we also include positive externalities of residential density. This model offers simplicity and, through the endogenous city boundary, the extensive margin of agglomeration and dispersion forces. The second is the quantitative model of Berlin of Ahlfeldt et al. (2015), whose estimated amenity and production externalities allow the optimal policy to be quantified.

In the monocentric city model, we show that the tax schedule that maximizes equilibrium utility has two components: a Pigouvian subsidy equal to the marginal external benefit of agglomeration, and a tax proportional to housing expenditure and to the share of land rents that is not captured. The second component decreases with the distance to the center under mild conditions, so it taxes central locations and, net of the lump-sum rebate, subsidizes peripheral ones. In a quantification with United States parameters and positive agglomeration externalities, the optimal city has a larger extension than the market allocation whenever the capture share is 90% or less, and a naive implementation of the Pigouvian subsidy alone decreases equilibrium utility except when land rent capture is nearly complete.

In the quantitative model of Berlin, the instrument that maximizes expected utility has a closed form for any capture share: it consists of the income tax and the agglomeration subsidies that are optimal under full rent capture (Fajgelbaum and Gaubert, 2020), plus an ad valorem tax on residential and commercial floor space proportional to the share of land rents that is not captured. Like the second component in the monocentric model, this tax has a Pigouvian interpretation: it charges each unit of floor space the marginal land rent that its construction generates for absentee owners. In the Berlin calibration, under zero land rent capture, the optimal policy raises residents' utility by up to 7.1 percent relative to the income tax alone and lowers aggregate land rents by more than a fifth, whereas a naive implementation of the agglomeration subsidies alone achieves only 55 percent of the maximum possible gains over laissez-faire.

In short, different forces shape optimal density in a real city, and they may pull in opposite directions. Agglomeration externalities make concentration valuable and call for a denser city. Partial land rent capture pulls the other way: a share of the rents that density creates leaves with absentee owners, so the competition for central land drains resources from the city. In both the monocentric model and the quantitative model of Berlin, the optimal policy corrects each force, subsidizing agglomeration and taxing the leaked rents, so which one dominates is a quantitative question. In the Berlin calibration, at every capture share the optimal city is less densely built than the market city, with 1 to 30 percent less floor space per unit of land, and only agglomeration economies far stronger than what the empirical evidence supports would reverse these results. Duranton and Puga (2020) list the transfer of rents to absentee owners among the wedges between the private and the social value of density, and write that "much less is known about the wedge from land capitalization." They add that the key issue is whether the agents choosing density bear the full costs and benefits of their choices, which is exactly what the capture share measures.

The rest of the paper is structured as follows. Section 2 relates our paper to the literature. Section 3 presents the monocentric model, characterizes the two-part optimal tax schedule, and quantifies it with United States parameters. Section 4 derives the closed-form optimal policy in the quantitative model of Berlin, decomposes its welfare gains across instruments, and maps the optimal-versus-market density comparison over the capture share and the strength of externalities. Section 5 concludes.

2 Relation to the literature

Our paper contributes to the literature that studies the efficient spatial distribution of economic activity. An early antecedent is Rossi-Hansberg (2004), who characterizes the optimal allocation and the taxes that decentralize it in a city with production externalities. In a spatial equilibrium with many locations, Fajgelbaum and Schaal (2020) study the optimal design of transport networks. Fajgelbaum and Gaubert (2020) develop a framework that combines elements of quantitative trade and location choice models with heterogeneous workers to study the first-best spatial allocations and the transfers and subsidies needed to implement them. They show that there is scope for welfare-enhancing spatial policies even when spillovers are common across locations. However, they assume that workers collectively own a national portfolio of the returns to fixed factors. In a variant with local ownership, which they note is formally equivalent to absentee landlords, their optimal-transfer gains rise from 4.0 to 4.9 percent. This paper shows that there is scope for welfare-improving spatial policies even without spillovers and heterogeneity, provided that land rents, or returns to fixed factors, are not fully redistributed.

A small set of studies varies the ownership of rents across scenarios and consistently finds that it is quantitatively decisive. Eeckhout and Guner (2015) vary the share of land held by owners outside the planner's objective in a system of cities and find that the welfare gain of the optimal income-tax reform shrinks by more than an order of magnitude as that share rises. Parkhomenko (2023) shows that distinguishing owners from renters reduces the welfare gains of land-use deregulation to a fraction of the output gains, and Bunten (2017) that assigning construction rents to absentee owners reverses the sign of residents' welfare change from zoning abolition. Favilukis and Van Nieuwerburgh (2021) quantify the welfare cost of out-of-town ownership itself for New York and Vancouver. Relatedly, Favilukis et al. (2023) show that the welfare effects of housing policy in New York depend on the split of the population between renters, owners, and landlords.

Fajgelbaum and Gaubert (2025) make the closest contact: they show that local ownership of fixed factors distorts location choices even without spillovers, because location choices become tied to high rents per se, and they derive the transfer that corrects the distortion as a function of the local ownership shares. In their framework, however, every ownership split reallocates rents within the economy and the welfare objective, and with housing in fixed supply the correction is a location-based transfer. Our capture share governs rents that leave both, and the distortion it creates arises on the construction margin, which location-based transfers cannot reach. Relative to this literature, our contribution is to characterize the optimal instrument for any capture share. In the quantitative model the instrument has a closed form in which the parts that correct preference heterogeneity and externalities do not depend on rent capture, and the entire adjustment operates through a property tax. This makes it possible to map the welfare case for densification over the capture share, which none of these studies does.

We contribute to the literature that analyzes place-based policies (e.g., Kline and Moretti, 2014a,b; Gaubert et al., 2025). The dispersion force we identify interacts with the other policy instruments studied for cities with externalities. Just as with the Pigouvian subsidy, it will affect the properties and desirability of, for example, income taxes (e.g., Tscharaktschiew and Hirte, 2010), property taxes (e.g., Kono et al., 2019; Song and Zenou, 2006), city-specific minimum wages (e.g., Pérez, 2022), Pigouvian congestion pricing (e.g., Brinkman, 2016; Zhang and Kockelman, 2016; Mun et al., 2005; Verhoef, 2005), and land use regulations (e.g., Turner et al., 2014; Anas and Rhee, 2007; Brueckner, 2007), among others. These analyses typically fix who receives the land rents, so how their instruments perform under partial rent capture remains an open question.

Our work also adds to the recent and fast-growing literature that uses quantitative spatial models of cities to estimate the welfare effects of transportation infrastructure and other interventions (e.g., Desmet and Rossi-Hansberg, 2013; Monte et al., 2018; Severen, 2023; Tsivanidis, 2026). The treatment of land ownership in these types of models is diverse. For example, in Ahlfeldt et al. (2015), there is an absentee landlord, and the land rents are neither taxed nor spent within the city. Heblich et al. (2020) assume that floor space is owned by landlords who spend the entire rent on consumption goods. In Couture et al. (2024), rents are rebated to landlords who consume in the city, and in Almagro and Domínguez-Iino (2025) part of the housing stock serves tourists. Allen and Arkolakis (2022) abstract from modeling the housing market. The welfare measure varies as well: some studies evaluate allocations by the utility that residents attain in equilibrium, others by the resources the city uses to sustain a given utility level, and others by the sum of surpluses, which adds the land rents to the residents' side. The first two objectives select the same allocation when land rents are fully captured and part ways when capture is partial (Basso et al., 2024). Donald et al. (2026) decompose aggregate welfare changes in spatial models into technology, externality, and redistribution terms. Quantitative spatial models routinely pair the residents' utility measure with an absentee landlord and no rent capture, precisely the configuration in which the measures diverge the most. We keep the residents' utility measure of that literature and make the role of the capture share explicit.

3 Monocentric city model

3.1 Basics and equilibrium

We begin our analysis with the monocentric city model with homogeneous individuals. As discussed above, this model, unlike the quantitative spatial model of Section 4, allows us, given its simplicity, to study the optimal city extension and to isolate the main force behind our results.

We build on the monocentric city model's simplest version by incorporating positive residential externalities. There are H identical households that choose where to live along a closed linear city parametrized by $0 \leq x \leq \bar{x}$, where the CBD and the endogenous city boundary are located at $x = 0$ and $x = \bar{x}$, respectively.[2] All city residents work at the CBD, earn y as income, and commute from their residential location using a single mode (e.g., private car). Commuting costs increase linearly with the distance to the CBD and include both the trip's time cost and the vehicle's operating cost. Each household maximizes its utility $U = B(n(x)) \cdot u(c,l)$, where $u(c,l)$ is a quasi-concave function that depends on the consumption of a composite good c and housing l, measured as floor space, both depending on the location, and B represents the agglomeration externalities.

To account for these agglomeration forces, B depends on the residential density at x, $n(x)$, and captures residential amenities that arise from natural advantages (e.g., leafy streets) and from residential externalities, both positive and negative. Examples of positive externalities include increasing returns to scale in producing neighborhood amenities, and of negative externalities, such as crime (Redding, 2023). The empirical literature reports positive and highly localized residential amenities in real cities, i.e., positive externalities due to agglomeration usually offset negative ones (see, e.g., Ooi and Le, 2013; Zahirovich-Herbert and Gibler, 2014; Ahlfeldt et al., 2015; Ahlfeldt and Pietrostefani, 2019).

The trade-off in the model is, as usual, between transportation costs and dwelling size. The price of c is normalized to one irrespective of location, while the price of l is denoted by Q and varies with location. At the city boundary, the residential rent $Q(\bar{x})$ must equal the exogenous agricultural rent Q_a. This notation follows Ahlfeldt et al. (2015) to maintain consistency with the model of Section 4.

To model different land rent capture scenarios, we consider that the city government collects taxes on the excess land rents of absentee landlords at a rate equal to $\mu \in [0,1]$. The revenue from this tax is distributed equally among residents. As in Papageorgiou and Pines (1999), by varying μ, we allow for various scenarios that range from a complete redistribution of land rents ($\mu = 1$) to the traditional approach in urban economics of abstracting from these rents ($\mu = 0$). Absentee

[2] Considering a circular city with a dense radial road network does not change any of the results of this section. The only difference would be that the density function must be multiplied by $\theta(x)$, where $\theta(x)$ is the number of radians of land available at each x.

landlords spend the untaxed portion of their rents elsewhere. Throughout the paper, μ is a primitive of the economy rather than a policy choice: welfare (residents' utility) trivially increases with μ. Our research question is, rather, the optimal spatial policy at a given μ.

We first briefly characterize the equilibrium in the absence of taxes and subsidies to show the role of the excess land rents in the welfare analysis. The first equilibrium component is the individual maximization problem:

$$\max_{c,l} \quad B(n(x)) \cdot u(c(x), l(x)) \tag{1a}$$

$$\text{s.t.} \quad y + \frac{\mu R}{H} = tx + c(x) + Q(x)l(x) \tag{1b}$$

$$\text{with} \quad R = \int_0^{\overline{x}} Q(x) - Q_a \, dx \tag{1c}$$

where $n(x)$ is the residential density at x and consequently, $B_n' \geq 0$. Equation (1b) is the budget constraint, with t the commuting cost per mile, and $\mu R/H$ the lump-sum transfer of the revenue from taxation on land rents, as defined by Equation (1c).

The remaining components are as follows: there is indifference across locations (2a), the residential rent equals the agricultural rent at the city boundary (2b), the urban population H fits in the city (2c), and the residential density is inversely proportional to housing consumption (2d).

$$B(n(x)) \cdot u(c(x), l(x)) = \overline{U}, \quad 0 \leq x \leq \overline{x} \tag{2a}$$

$$Q(\overline{x}) = Q_a \tag{2b}$$

$$\int_0^{\overline{x}} n(x) dx = H \tag{2c}$$

$$n(x) = \frac{1}{l(x)}, \qquad 0 \leq x \leq \overline{x} \tag{2d}$$

When the residential externality is not too strong, the model leads to the usual properties of urban equilibrium gradients along the city: when moving away from the CBD, housing prices decline, housing consumption increases, and population density decreases.

3.2 Welfare analysis

In the presence of positive residential externalities, a natural strategy may be to encourage agglomeration by subsidizing residence in high-density areas. The policy intervention we consider is a location-specific tax or subsidy that we denote $\tau(x)$. If the aggregate result of $\tau(x)$ along the city is a surplus, the surplus is redistributed lump sum to all residents. If the aggregate result is a deficit, the deficit is financed through a lump-sum transfer from all residents. We study the tax-subsidy schedule that maximizes the residents' equilibrium utility. This is the relevant welfare measure because the utilitarian first-best allocation requires utility to vary over space (Mirrlees, 1972), which no equilibrium with freely mobile identical residents can sustain, so we restrict attention to the equilibrium outcomes reached after the intervention. It is also the usual measure of welfare in quantitative models (e.g., Fajgelbaum and Gaubert, 2020; Tsivanidis, 2026), and evaluating policy by the residents' welfare while land rents accrue, at least in part, to owners outside the objective is common practice (e.g., Papageorgiou and Pines, 1999; Bertaud and Brueckner, 2005; Eeckhout and Guner, 2015; Coulombel, 2017; Hsieh and Moretti, 2019; Liang et al., 2024; Balboni, 2025). The welfare maximization problem is:

$$(P) \qquad \max \quad \overline{U} \tag{3a}$$

$$\text{s.t.} \quad B(n(x)) \cdot u(c(x), l(x)) = \overline{U}, \qquad 0 \leq x \leq \bar{x} \tag{3b}$$

$$\frac{\mu R}{H} + \frac{G}{H} + y = tx + \tau(x) + c(x) + Q(x)l(x) \qquad 0 \leq x \leq \bar{x} \tag{3c}$$

$$Q(x) = \frac{u_l(c(x), l(x))}{u_c(c(x), l(x))}, \qquad 0 \leq x \leq \bar{x} \tag{3d}$$

$$G = \int_0^{\bar{x}} \frac{\tau(x)}{l(x)} dx \tag{3e}$$

$$R = \int_0^{\bar{x}} Q(x) - Q_a \, dx \tag{3f}$$

$$\int_0^{\bar{x}} \frac{1}{l(x)} dx = H \tag{3g}$$

$$Q(\bar{x}) = Q_a \tag{3h}$$

In problem (P), (3b) restricts the outcome to be an urban equilibrium (spatial mobility). (3c) is the individual's budget constraint expanded to include $\tau(x)$ on the right-hand side, the tax to be paid by residents living at x, and G/H on the left-hand side, the lump-sum redistribution of the tax revenue. (3d) requires that households divide their expenditure between the composite good and floor space optimally at the prevailing prices, so the allocation can be decentralized. (3e) defines the amount of tax revenue, (3f) defines the excess land rents, (3g) establishes that the total urban population H fits inside the city, and (3h) indicates that the residential rent equals the agricultural rent at the city boundary. Note that by construction, the tax policy is revenue-neutral. Therefore, residents may be subsidized on net at some locations and taxed on net at others.

The following proposition summarizes the optimal spatial policy.

Proposition 1. *The allocation that maximizes equilibrium utility can be decentralized by imple-*

menting the spatially dependent tax schedule $\tau(x)$*:*

$$\tau(x) = \underbrace{-MEB(x)}_{\tau_1} + \underbrace{(1-\mu)\frac{Q(x)l(x)}{|\sigma(x)|}}_{\tau_2}$$

where $MEB(x)$ *is the marginal external benefit of agglomeration and* $\sigma(x) < 0$ *is the income-compensated price elasticity of the demand for housing, evaluated at the bundle* $(c(x), l(x))$.

Proof. Appendix A. □

Remark 1. In the absence of externalities, utility is constant across locations and $\sigma(x)$ coincides with the gradient ratio $\left(\frac{\partial l}{\partial x}\Big/\frac{\partial Q}{\partial x}\right)\frac{Q(x)}{l(x)}$, so the elasticity can be read directly from the equilibrium profiles. With externalities the gradient identity no longer holds, but the elasticity form of τ_2 remains valid because it is a pointwise property of preferences (Lemma 1 in Appendix A).

The optimal intervention has two components. The first is a Pigouvian subsidy, designed to align private incentives with social optimality by internalizing positive externalities. Without this subsidy, individuals would underprovide residential spillovers and agglomerate less than is efficient. However, implementing an instrument that includes only this component would raise land rents by increasing agglomeration. This might be undesirable when $\mu < 1$, as a fraction of these land rents exits the economy. Therefore, when capture is partial, the second component mitigates this effect by reducing land rents.

We now show in Proposition 2 that, under mild conditions, the second component of the optimal tax works as a dispersion force: it decreases with distance, discouraging agglomeration and promoting the spatial extension of the city.

Proposition 2. *Consider the model without externalities, in which the optimal tax reduces to* $\tau_2(x) \equiv (1-\mu)Q(x)l(x)|\sigma(x)|^{-1}$*, and let* $|\sigma(Q)|$ *denote the elasticity as a function of the price along the equilibrium indifference curve. Suppose that the demand for housing is inelastic,* $-1 < \sigma < 0$*, and that* $|\sigma(Q)|$ *is non-increasing in* Q*. Then, in the equilibrium induced by* τ_2 *with* $\mu < 1$*: (a) the floor space price decreases with distance; (b)* $\tau_2'(x) < 0$ *for all* $x \in [0, \bar{x}]$*, so the tax falls on central locations and, net of the lump-sum rebate, subsidizes peripheral ones; and (c) provided the induced equilibrium utility exceeds the market level and floor space is a normal good, the city is strictly more extended than in the market equilibrium. These conditions hold, for example, for Cobb-Douglas utility functions* $u(c,l) = c^{1-\beta}l^{\beta}$*, where* $\sigma = \beta - 1$*, and for CES utility functions* $u(c,l) = ((1-\beta)c^{\rho} + \beta l^{\rho})^{\frac{1}{\rho}}$ *with* $\rho < 0$.

Proof. Appendix B. □

Proposition 1 shows that except for the extreme case of a complete capture of excess land rents, i.e., $\mu = 1$, the optimal policy includes a location-specific tax on top of the subsidy equal to the marginal external benefit of agglomeration. This second component is an ad valorem tax on housing, charging each household the fraction $(1-\mu)/|\sigma(x)|$ of its expenditure $Q(x)l(x)$, and it has a Pigouvian interpretation as well. The land at each location is fixed, so a household that demands one additional unit of housing at x must bid it away from other residents, which raises the land rents of the location by $1/|\sigma(x)|$ times the price of housing. Of this increase, a fraction $(1-\mu)$ accrues to absentee owners and leaves the economy. Therefore, the tax charges each unit of housing exactly this marginal leakage.

Following Proposition 2, the tax decreases with the distance to the CBD under mild conditions. Since tax revenue is then distributed lump-sum, the actual effect of τ_2 is to tax locations close to the CBD while subsidizing farther areas, which in turn induces the spatial extension of the city.

The intuition behind this result is as follows. First, Proposition 1 indicates that there is no room for welfare improvement beyond the Pigouvian subsidy when land rents are fully captured and redistributed. Yet, when the fraction of land rents that is not captured is positive, there is scope for welfare-enhancing dispersion. This force works as an indirect transfer of land rents from absentee landlords to the residents, yielding higher welfare. It does so by making the city center more expensive and the outskirts more attractive, which reduces the competition for space close to the city center and, with it, the excess land rents. Note that the higher equilibrium utility is for everyone, including those at places near the CBD whose tax exceeds the lump-sum compensation: the utility achieved in equilibrium with this intervention is higher because floor space is cheaper. In contrast, in places near the city boundary, the redistribution minus the tax, $G/H - \tau(x)$, translates into a subsidy. The floor space price increases, but it is more than compensated by the increase in income.[3]

In the monocentric model the same instrument can also be read as an income tax. For instance, when the utility is represented by a Cobb-Douglas function of the form $u(c,l) = c^{1-\beta} l^{\beta}$, the tax is $(1-\mu)\frac{\beta}{1-\beta}\bar{y}(x)$, with $\bar{y}(x)$ being the income net of transportation costs and taxes at x.[4] Consequently, in this case, the second component of τ can be understood as an income tax with a flat rate of $(1-\mu)\frac{\beta}{1-\beta}$. That one instrument admits both readings reflects the simplicity of the monocentric model: every household earns the same income and spends on housing a fixed share of what remains after commuting costs and taxes, so a tax proportional to housing expenditure is also a tax proportional to net income. Disentangling the two readings is one motivation for the quantitative model of Section 4, where floor space is produced with capital and rented by firms

[3]Formally, $G/H - \tau(x) < 0 \; \forall x \in [0, x^*)$ and $G/H - \tau(x) > 0 \; \forall x \in (x^*, \bar{x}]$, for some $x^* \in (0, \bar{x})$.

[4]$\bar{y}(x) = \frac{\mu R}{H} + \frac{G}{H} + y - tx - \tau(x)$. This base subtracts the tax itself. On income before the tax, the equivalent flat rate is $(1-\mu)\beta/(1-\mu\beta)$, which equals β under an absentee landlord.

as well as households. There the ad valorem reading is the correct one: the leakage arises on the construction margin and falls on both uses of floor space, so the entire dependence of the optimal policy on μ operates through the tax on floor space, which an income tax cannot replicate.

3.3 Quantification

To build intuition about the practical importance of the results presented above, we simulate the urban equilibria of a city for different values of μ: the laissez-faire equilibrium, the optimal-tax equilibrium, and the equilibrium with only the Pigouvian subsidy. We base our numerical analysis on US values, with parameters summarized in Table 1. For the simulations, we use a Cobb-Douglas utility function $u(c,l) = c^{1-\beta} l^{\beta}$, setting $\beta = 0.35$. This implies that every household spends 35% of their income net of transportation costs on housing, which is consistent with the average expenditure reported in the Consumer Expenditure Survey (US Department of Labor, 2018).[5] The hourly wage is set at US$25.27, which, following Bertaud and Brueckner (2005), is obtained using the 2018 US median household income (US$63,179, Census Bureau estimates from the Current Population Survey) and assuming 2,000 work hours per year per worker and 1.25 workers per household. Commuting costs are proportional to distance: each mile commuted takes $1/v$ hours at a speed of $v = 15$ miles per hour and is valued at the hourly wage, over two daily round trips per household worker and 250 working days per year, so that $t = 2 \times 250 \times 1.25 \times w/v \approx$ US$1,053 per mile per year. For the agricultural rent value, we also follow Bertaud and Brueckner (2005): we consider the average value of US farm real estate for 2019 of US$3,160/acre. Assuming a 5% discount rate, we obtain $Q_a =$ US$101,120/sq. mi. We set $H = 120,000$ households, which is equivalent to roughly $800,000$ households in a circular city rather than the linear city of our model.

Table 1: Main parameter values.

Parameter	Value
$u(c,l)$	$c^{1-\beta} l^{\beta}$
β	0.35
y [$]	63,179
Q_a [$/sq. mi]	101,120
H [households]	120,000
t [$/mile/year]	1,053
v [miles/hour]	15
γ	{0.03, 0.1}
μ	{0,0.5,1}

[5] The Consumer Expenditure Survey reports an average income net of taxes and transportation costs of US$57,480, of which US$20,091 is spent on housing.

Additionally, we assume that the utility attained by residents located at x can be written as:

$$n(x)^{\gamma} \cdot u(c(x), l(x)) \tag{4}$$

where $n(x)$ is the residential density at x, and γ is a parameter that captures both the sign and intensity of the agglomeration externalities. Based on previous literature, we set $\gamma = 0.03$.[6]

Figure 1 depicts the two components of the optimal instrument presented in Proposition 1 when $\mu = 0$. τ_1 is the subsidy that internalizes the agglomeration spillovers, and τ_2 is the tax due to partial land rent capture. The optimal instrument is then given by $\tau = \tau_1 + \tau_2$. These components do not account for revenue redistribution, and consequently $\tau_1(x) < 0$ and $\tau_2(x) > 0 \; \forall x$. For clarity, a dot on each curve indicates the point where each component, once redistribution is considered, changes sign, for instance from a subsidy in the inner city to a tax in the outer city in the case of τ_1.

Figure 1 indicates that, in our simulations, the inefficiencies caused by partial land rent capture dominate the agglomeration externality effect. Consequently, a social planner would prefer to promote the extension of the city by imposing high taxes in the city center. Figures 2 and 3 show the outcome, comparing the market equilibrium with the optimal instrument $\tau_1 + \tau_2$. With each city's land ordered from densest to least dense, and from highest to lowest priced, the optimal city is less dense and cheaper than the market city over the entire range of land. Appendix D reports the underlying profiles over distance to the CBD, including the agglomeration subsidy τ_1 alone: the subsidy steepens the price and density gradients at the center, while the optimal instrument flattens both and extends the city outward.

Table 2 summarizes the results regarding equilibrium utility, city extension and land rents. First, implementing the optimal tax increases utility between 0.02% and 1.7%. We also find that subsidizing the marginal external benefit of agglomeration but ignoring the component related to land rent capture decreases welfare. For $\mu = 0$ and $\mu = 0.5$, a naive implementation of a Pigouvian instrument decreases the equilibrium utility. Only when the majority of the land rents are captured and redistributed does the naive Pigouvian instrument alone increase welfare.

As Table 2 shows, charging the optimal tax has a sizable effect on the urban form. The optimal city is more extended than the unpriced city for a wide range of values of μ. For $\mu = 0$, the city under the optimal tax is 17.4 miles longer than the unpriced city (a 32.0% increase). For $\mu = 0.5$, the optimal city is 15.1% longer than the unpriced city, and only when μ reaches 1 is the optimal city marginally shorter than the market city. At the same time, the optimal instrument reduces the excess land rents for low values of μ by decreasing rental prices in the inner city,

[6]The meta-analysis conducted in Ahlfeldt and Pietrostefani (2019) reports a citation-weighted mean density elasticity of *quality of life* of 0.03 (standard deviation 0.07). Additionally, the mean density elasticity of labor productivity sits around 0.04.

as explained above. For most values of μ, the Pigouvian subsidy alone operates precisely in the opposite direction to the optimal tax, reducing the extension of the city while increasing the excess land rents. It is only for high values of μ that the optimal tax is closer to the Pigouvian instrument, producing similar effects on the urban form. In summary, unless land rent capture is almost total, the scope for agglomeration subsidies is narrower than the externality alone suggests.

Figure 1: Components of the optimal instrument at $\mu = 0$ and $\gamma = 0.03$: the agglomeration subsidy τ_1, the rent-capture component τ_2, and the total τ. Dots mark the locations where each component changes sign once the lump-sum rebate is considered.

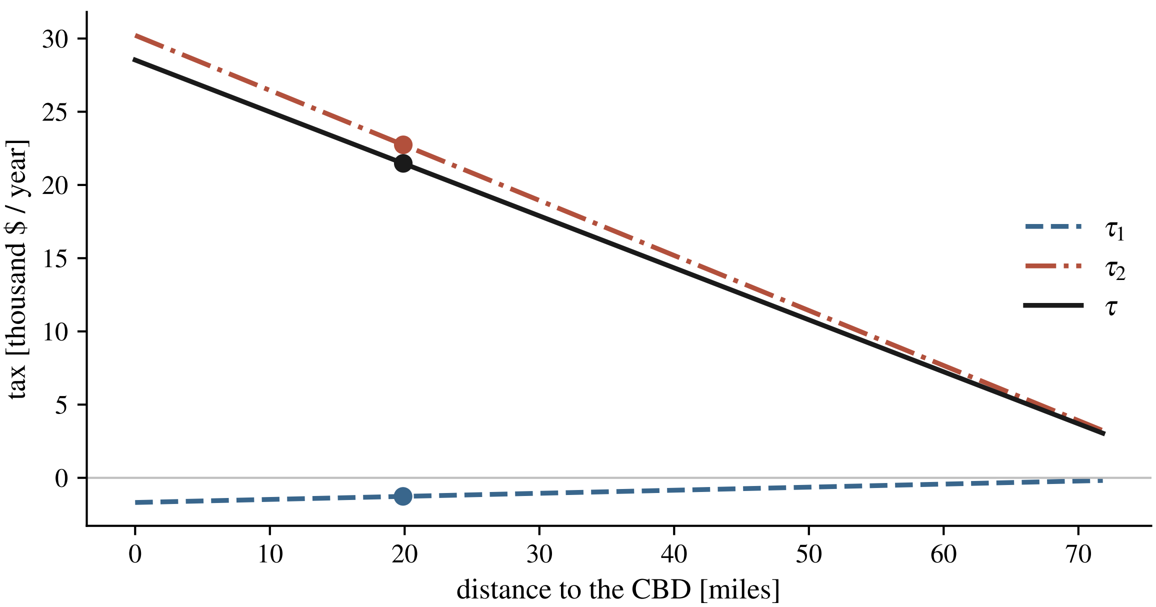


Table 2: Equilibrium results: no instruments vs. agglomeration subsidies vs. optimal instrument.

μ	0			0.5			1		
Instrument	Unpriced	τ_1	$\tau_1 + \tau_2$	Unpriced	τ_1	$\tau_1 + \tau_2$	Unpriced	τ_1	$\tau_1 + \tau_2$
Equilibrium utility $\bar{u}$	37.99	37.89	38.62	43.55	43.49	43.75	51.05	51.06	51.06
City extension [miles]	54.40	53.22	71.81	62.63	61.34	72.11	73.78	72.37	72.37
Aggregate land rents [millions US$]	1,991.14	2,006.16	1,766.95	2,292.14	2,312.07	2,144.75	2,700.34	2,728.04	2,728.04

A final question is when agglomeration externalities would dominate the dispersion force of partial land rent capture. To answer it, we now vary the strength of the externality.

Figure 4 maps the answer: each cell reports the percentage change in average residential density, $H/\bar{x}$, between the optimal-policy and the market equilibrium at each (μ, γ) pair. The partial land rent capture force dominates the externality throughout the empirically relevant range: for any capture share up to three quarters, the optimal city is less dense than the market city, for externalities from zero to more than three times the estimated elasticity (the outlined row), and the gap moves little with γ. Densification is optimal only when rent capture is nearly complete, where the

Figure 2: Residential density in the monocentric city at $\mu = 0$ and $\gamma = 0.03$: market equilibrium versus the optimal instrument, with land ordered densest first.

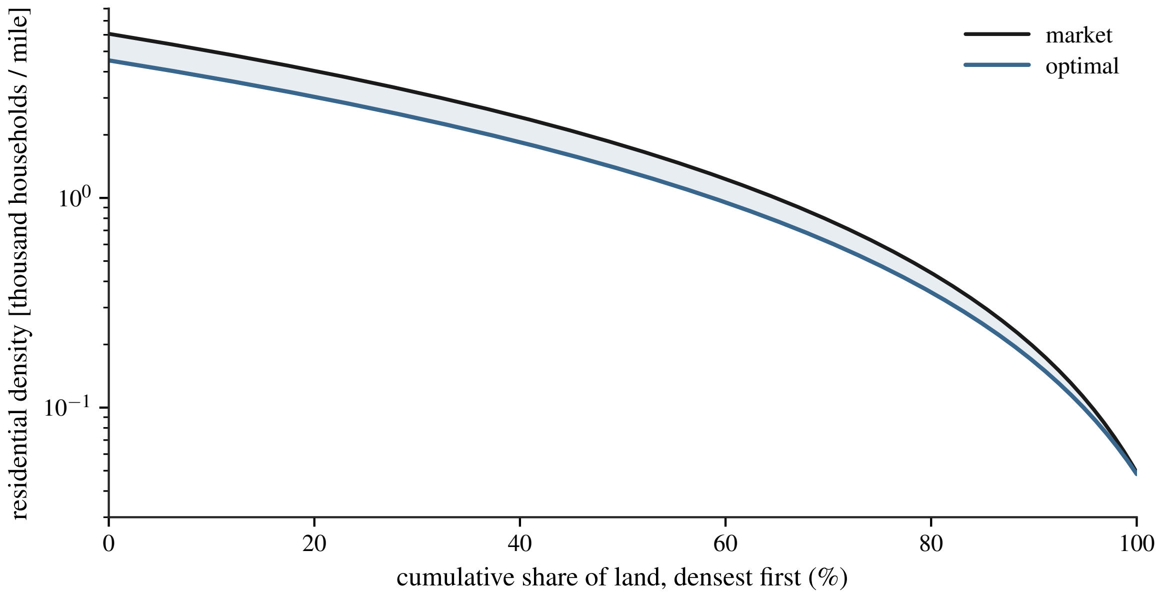
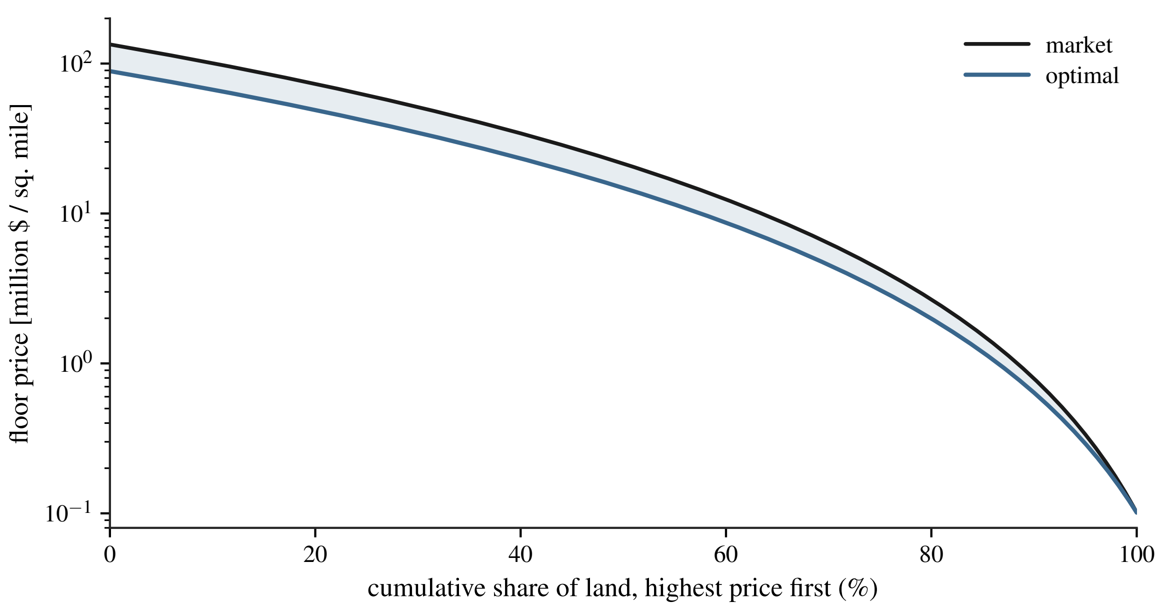


Figure 3: Floor price in the monocentric city at $\mu = 0$ and $\gamma = 0.03$: market equilibrium versus the optimal instrument, with land ordered highest-priced first.



optimal instrument approaches the pure Pigouvian subsidy. With no externality and full capture the market city is exactly optimal.

Figure 4: Optimal versus market density in the monocentric model, across capture shares and externality strengths. Each cell is the percentage change in average residential density $H/\bar{x}$ under the optimal instrument relative to the market equilibrium at the same (μ, γ).

4 Optimal taxes in a quantitative model

4.1 Quantitative models

The monocentric city model is helpful for its simplicity in building intuition but is not sophisticated enough for quantifying policies. This section studies optimal taxes in a quantitative spatial model of a city. Unlike the monocentric model, the quantitative model of a city includes the firm's location choice, endogenous wages, residential and commercial floor space developers, and commuting costs that depend on the transportation network. For example, we can differentiate the effects of an income tax from a property tax. Models of this type have been estimated structurally to study the economies of density (Ahlfeldt et al., 2015) and the impact of transportation infrastructure on various outcomes (see, e.g., Heblich et al., 2020; Allen and Arkolakis, 2022; Zárate, 2022;

Tsivanidis, 2026).

However, the welfare-maximizing allocation in this framework has received little attention. To our knowledge, Fajgelbaum and Gaubert (2020) were the first to study optimal spatial policies in an economic geography framework with spillovers. They show that when workers have idiosyncratic preferences for locations drawn from a Fréchet distribution, there is a welfare-enhancing spatial policy because of distributional concerns. As the planner cannot condition taxes or subsidies on the preference draws, she will have incentives to redistribute income to locations where individuals have a higher marginal utility of housing consumption (as a consequence of their preference draw). Tsivanidis (2026) also notes that in a version of his model with collective ownership of land rents, no spillovers, and residential preference draws, a labor income tax redistributed lump sum maximizes welfare.

Both studies find that it is optimal to implement a linear income tax with a rate of $1/(1+\varepsilon)$, where ε is the Fréchet shape parameter. This effect is always present. It is an outcome specific to the random utility framework and is not related to land rent capture, which is our focus. As discussed in the introduction, the treatment of land ownership in these models ranges from absentee landlords whose rents leave the city (Ahlfeldt et al., 2015) to collective ownership of a national portfolio of the returns to fixed factors (Fajgelbaum and Gaubert, 2020), yet none of them considers partial capture in the sense we study: rents that exit the economy and the welfare objective. Fajgelbaum and Gaubert (2025) vary the locally owned share of the returns to fixed factors and show that the market allocation is distorted generically for any split, but every split keeps the rents inside the objective and the correction is a location-based transfer.

In this section, we characterize the optimal policy when land rents are not fully captured. We show that the optimal instrument admits a closed form for any capture share: it consists of the Fréchet income tax and the agglomeration subsidies that are optimal under full rent capture, all unchanged, plus an ad valorem tax on floor space whose rate is proportional to the share of rents that is not captured. We use the model and the estimation of Berlin provided in Ahlfeldt et al. (2015) and adapt it to accommodate the land ownership and tax scenarios we are interested in. Both agglomeration forces of the original model remain active throughout: the residential amenity externality and the production externality, each at its estimated strength.

4.2 The Berlin model

The model's exposition and notation closely follow those of Ahlfeldt et al. (2015). However, in the theoretical analysis, we simplify some elements that are not key to our exposition. Consider a closed city with S discrete blocks, each with a land area denoted by K_i, $i = 1, \ldots, S$. In every block, floor space is provided by developers who use the block's land as their only fixed input, and it is allocated between residential and commercial use endogenously, by the price mechanism described below. We assume that an exogenous number of workers H populate the city, and they attain an endogenous expected equilibrium utility $\overline{U}$ (i.e., a closed city).

To simplify the analysis, we consider that floor space developers own the land they use. However, the city government imposes a tax rate on the land rents equal to $\mu \in [0,1]$ and then distributes its revenue equally among residents. Thus, μ is the share of the returns to land that accrues to workers in equal parts, and $1-\mu$ is the share that is not spent within the city. When $\mu = 0$, we recover the assumption of having an absentee landlord whose rents are untaxed, as in the original model of Ahlfeldt et al. (2015), and when $\mu = 1$, collective ownership or full capture of land rents. As in the monocentric model, welfare is the residents' expected utility, while the untaxed share of the rents accrues to owners outside the objective. We once again treat μ as exogenous because we are interested in assessing its impact on the optimal spatial concentration of economic activity. Just as in the monocentric city model, it is trivial that $\mu = 1$ achieves the highest welfare.

4.2.1 Workers

Every worker chooses a residential location and a working location. The utility U_{ij} that a worker obtains when living in block i and working in block j is assumed to take a Cobb-Douglas form with parameter $0 < \beta < 1$.[7] Utility is derived from the consumption of a numeraire good c_{ij} and housing l_{ij}:

$$U_{ij} = \frac{B_i z_{ij}}{d_{ij}} \left(\frac{c_{ij}}{\beta}\right)^{\beta} \left(\frac{l_{ij}}{1-\beta}\right)^{1-\beta} \tag{5}$$

In Equation (5), B_i represents residential amenities in block i. To model agglomeration externalities, we assume that residential amenities can be expressed as:

$$B_i = b_i \left[\sum_{r=1}^{S} e^{-\rho t_{ir}} \left(\frac{H_{Rr}}{K_r}\right)\right]^{\eta} \tag{6}$$

where H_{Rr}/K_r is residence employment density per unit of land area. Then, d_{ij} is an iceberg commuting cost such that $d_{ij} = \exp(\kappa \cdot t_{ij})$, where t_{ij} is the commuting time between blocks i and j. z_{ij} is an idiosyncratic utility shock capturing the idea that workers can have idiosyncratic reasons for living and working in different blocks in the city. We assume that the shock z_{ij} is drawn independently across residence and workplace pairs (i,j) and across workers from a Fréchet

[7]Notation in this section is self-contained and follows Ahlfeldt et al. (2015), with one exception: since μ denotes the capture share throughout the paper, we write λ for the capital share in construction and λ_A for the production externality elasticity, which they denote μ and λ. Relative to Section 3, two symbols change meaning: β denotes here the expenditure share on the consumption good, so that the housing share is $1-\beta$, and the elasticity of amenities with respect to density is denoted η, with γ reserved for a constant derived from the Fréchet distribution.

distribution with scale parameters $T_i > 0$ and $E_j > 0$, and shape parameter $\varepsilon > 1$:

$$F(z_{ij}) = e^{-T_i E_j z_{ij}^{-\varepsilon}} \tag{7}$$

After observing her realizations of the idiosyncratic shocks, each worker chooses a residential and a working block to maximize her utility, subject to an income constraint:

$$c_{ij} + l_{ij} Q_i = w_j + I \tag{8}$$

In Equation (8), Q_i is the residential floor space price in block i, w_j is the wage paid at block j, and I is the lump-sum transfer from the government coming from the tax revenue. The resulting indirect utility from living in block i and working in block j, u_{ij}, is:

$$u_{ij} = \frac{z_{ij} B_i \left[w_j + I\right] \left[Q_i\right]^{\beta-1}}{d_{ij}} \tag{9}$$

Using well-known properties of the Fréchet distribution, the probability that a worker chooses to live in block i and work in block j, π_{ij}, is given by:

$$\pi_{ij} = \frac{T_i E_j \left(d_{ij} \left[Q_i\right]^{1-\beta}\right)^{-\varepsilon} \left(B_i \left[w_j + I\right]\right)^{\varepsilon}}{\sum_{r=1}^{S} \sum_{s=1}^{S} T_r E_s \left(d_{rs} \left[Q_r\right]^{1-\beta}\right)^{-\varepsilon} \left(B_r \left[w_s + I\right]\right)^{\varepsilon}} \equiv \frac{\Phi_{ij}}{\Phi} \tag{10}$$

Letting R_i denote the land rents in block i, the lump-sum transfer is given by:

$$I = \frac{G}{H} + \frac{\mu \sum_i R_i}{H} \tag{11}$$

where G is the revenue from the tax policy under study, which we introduce in Section 4.3. The number of workers living in block i, H_{Ri}, is given by:

$$H_{Ri} = H \sum_{j=1}^{S} \pi_{ij} \tag{12}$$

Finally, as in Ahlfeldt et al. (2015), the expected utility that workers obtain, $\overline{U}$, is given by:

$$\overline{U} = \gamma \Phi^{1/\varepsilon} \tag{13}$$

where $\gamma = \Gamma\left(\frac{\varepsilon-1}{\varepsilon}\right)$ and $\Gamma(\cdot)$ is the Gamma function.

4.2.2 Firms

Firms operate under constant returns to scale, using floor space L_M and labor H_M as inputs to produce a single numeraire good. The production technology is assumed to take a Cobb-Douglas form with parameter $0 < \alpha < 1$, so that the output in block j, y_j, is given by:

$$y_j = A_j H_{Mj}^{\alpha} L_{Mj}^{1-\alpha} \tag{14}$$

In Equation (14), A_j is the productivity of firms in block j. In Ahlfeldt et al. (2015), productivity is subject to the same type of agglomeration externality as residential amenities,

$$A_j = a_j \left[\sum_{r=1}^{S} e^{-\delta_A t_{jr}} \left(\frac{H_{Mr}}{K_r} \right) \right]^{\lambda_A}, \tag{15}$$

where a_j is the exogenous production fundamental and the bracket aggregates the surrounding employment density with decay δ_A. Both the residential amenity externality and this production externality are active throughout the analysis, at the strengths estimated by Ahlfeldt et al. (2015). Section 4.4.2 reports an amenity-only exercise showing that the density comparison does not depend on the production externality. Firms choose labor and floor space to maximize their profit Π_j, as shown in Equation (16), where q_j is the commercial floor price. Profit maximization and the zero profit condition allow us to characterize the relationship between the demand for labor and floor space (Equation 17) and the equilibrium commercial floor price, q_j (Equation 18) for each block j where firms operate.

$$\Pi_j = y_j - w_j H_{Mj} - q_j L_{Mj} \tag{16}$$

$$H_{Mj} = \left(\frac{\alpha A_j}{w_j} \right)^{1/(1-\alpha)} L_{Mj} \tag{17}$$

$$q_j = (1-\alpha) \left(\frac{\alpha}{w_j} \right)^{\alpha/(1-\alpha)} A_j^{1/(1-\alpha)} \tag{18}$$

The labor market-clearing condition equates the number of workers employed in a block j with the number of workers choosing to work in that block:

$$H_{Mj} = \sum_{i=1}^{S} \frac{\pi_{ij}}{\sum_{s=1}^{S} \pi_{is}} H_{Ri} = \sum_{i=1}^{S} \frac{E_j \left(\left[w_j + I \right] / d_{ij} \right)^{\varepsilon}}{\sum_{s=1}^{S} E_s \left(\left[w_s + I \right] / d_{is} \right)^{\varepsilon}} H_{Ri} \tag{19}$$

4.2.3 Land market

Floor space L is the output of a sector that uses land K and capital M as inputs. In particular, the production function is

$$L_i = M_i^{\lambda} K_i^{1-\lambda} \tag{20}$$

Profit maximization and the zero profit condition allow us to characterize the relative demand for each input (Equation 21) and the equilibrium floor price (Equation 22).

$$M_i = \left(\frac{\lambda}{1-\lambda} \frac{\mathbb{R}_i}{\mathbb{P}} \right) K_i \tag{21}$$

$$\mathbb{Q}_i = \lambda^{-\lambda} (1-\lambda)^{-(1-\lambda)} \mathbb{P}^{\lambda} \mathbb{R}_i^{1-\lambda} \tag{22}$$

where $\mathbb{Q}_i = \max\{q_i, Q_i\}$ is the price for floor space, $\mathbb{P}$ is the price for capital, and $\mathbb{R}_i$ is the price for land. Then, land rents in block i, R_i, are given by $R_i = K_i \mathbb{R}_i$.

Residential floor space market clearing follows from workers' utility maximization, combined with the distribution of the idiosyncratic utility:

$$(1-\beta) \frac{\mathbb{E}\left(w_s + I \,|\, i \right) H_{Ri}}{Q_i} = L_{Ri} \tag{23}$$

In Equation (23), $\mathbb{E}\left(w_s + I \,|\, i \right)$ is the expected income of workers living in block i (Equation 24).

$$\mathbb{E}\left(w_s + I \,|\, i \right) = \sum_{s=1}^{S} \pi_{is|i} \left(w_s + I \right) \tag{24}$$

In Equation (24), $\pi_{is|i}$ is the probability that, conditional on living in block i, a worker chooses to work in block s:

$$\pi_{is|i} = \frac{\pi_{is}}{\sum_j \pi_{ij}} = \frac{E_s((w_s + I)/d_{is})^{\varepsilon}}{\sum_{j=1}^{S} E_j((w_j + I)/d_{ij})^{\varepsilon}} \tag{25}$$

Commercial floor space market clearing follows from the profit maximization and zero-profit conditions:

$$\left(\frac{(1-\alpha) A_j}{q_j} \right)^{1/\alpha} H_{Mj} = L_{Mj} \tag{26}$$

Finally, the numeraire good is freely traded. Summing the budget constraints of workers and the zero-profit conditions of firms, aggregate expenditure must equal aggregate income: what households and firms spend on goods and floor space equals the value of what the city produces plus the recycled rents,

$$H\sum_{ij}\pi_{ij}c_{ij}+\sum_{i}Q_iL_{Ri}+\sum_{j}q_jL_{Mj}=\sum_{j}y_j+\mu\sum_{i}R_i. \tag{27}$$

Substituting the developers' zero-profit condition, which splits every payment for floor space into capital costs and land rents ($\sum_i Q_iL_{Ri}+\sum_j q_jL_{Mj}=\mathbb{P}\sum_i M_i+\sum_i R_i$), yields the resource constraint of the economy (Lemma 3 in Appendix C):

$$\sum_{j}y_j=\underbrace{H\sum_{ij}\pi_{ij}c_{ij}}_{\text{residents' consumption}}+\underbrace{\mathbb{P}\sum_{i}M_i}_{\text{construction capital}}+\underbrace{(1-\mu)\sum_{i}R_i}_{\text{absentee owners' rents}}. \tag{28}$$

The city produces to consume, to pay for its construction capital, and to pay the rents that leave with absentee owners. Under full capture ($\mu=1$), the last term vanishes and (28) reduces to the standard resource constraint of models with full redistribution. A similar constraint with partial ownership appears in the theory of the monocentric city (Papageorgiou and Pines, 1999). In the welfare analysis of Section 4.3, where the planner maximizes the residents' welfare at a given μ, this term is a leakage that the optimal policy must confront.

Given the capture share μ and a tax policy, an equilibrium is a set of prices $\{Q_i,q_i,\mathbb{R}_i,w_i\}$ and an allocation of workers and floor space such that workers, firms, and developers achieve an individual optimum, amenities and productivities are consistent with the resulting densities, the conditions above hold, and the tax revenue is returned through the lump-sum transfer I. In the equilibrium without policy intervention, $G=0$ and $I=\mu\sum_i R_i/H$.

4.3 The optimal policy

We begin by showing that when land rents are fully captured, i.e., $\mu=1$, the instruments that maximize expected utility are as expected: an income tax related to the random utility framework, and subsidies linked to the residential and workplace locations that internalize the amenity and production externalities.

Proposition 3. *When the land rents are fully redistributed among city residents ($\mu=1$), the optimal tax can be written as:*

$$\tau_{ij}=\frac{1}{\varepsilon+1}w_j-\frac{\varepsilon}{\varepsilon+1}\left[\sum_{r,s}\gamma_{ri}\frac{H_{rs}x_{rs}}{H_{Ri}}\;+\;e_j\right] \tag{29}$$

where x_{rs} is the total expenditure of a worker living in r and working in s,

$$\gamma_{ri} = \eta \cdot e^{-\rho t_{ri}} \left(\frac{H_{Ri}}{K_i}\right) \left[\sum_{l=1}^{S} e^{-\rho t_{rl}} \left(\frac{H_{Rl}}{K_l}\right)\right]^{-1}, \qquad e_j = \frac{\lambda_A}{K_j} \sum_{l=1}^{S} \frac{y_l}{\Upsilon_l} e^{-\delta_A t_{jl}}, \tag{30}$$

and e_j is the marginal external product of employment in block j, with Υ_l the employment-density aggregate of (15). *The optimal instrument thus has the form $\tau_{ij} = \tau_j^W - \tau_i^R - \tau_j^E + C$, where τ_j^W is an income tax linked to the idiosyncratic shock, τ_i^R is a residential subsidy due to the amenity spillovers, and τ_j^E is a workplace subsidy due to the production spillovers.*

Proof. See Appendix C, where the result follows as the special case $\mu = 1$ of Proposition 4. □

As Fajgelbaum and Gaubert (2020) and Tsivanidis (2026) remark, full land rent capture is necessary for the instrument of Proposition 3 to maximize expected utility. Our main result characterizes the optimum for any capture share.

Proposition 4. *For any $\mu \in [0,1]$, the policy that maximizes expected utility consists of the location-based instrument of Proposition 3, unchanged, plus an ad valorem tax on residential and commercial floor space at the rate*

$$\delta_\mu = (1-\mu)\frac{1-\lambda}{\lambda},$$

under which occupants pay $(1+\delta_\mu)$ times the price received by developers and the revenue is rebated lump sum. The income-tax rate $1/(1+\varepsilon)$ and the agglomeration subsidies do not depend on μ: the entire dependence of the optimal policy on land rent capture operates through the property tax.

Proof. See Appendix C. □

The structure of the optimum follows from two conditions already in place. By the developers' zero-profit condition (21), the land rents of a block are proportional to the capital invested in it, $R_i = \frac{1-\lambda}{\lambda}\mathbb{P}M_i$. With the Cobb-Douglas technology (20), land earns the fraction $1-\lambda$ of the value of floor space and capital the fraction λ, at every block and at every scale. Substituting this proportionality into the resource constraint (28) collapses the leaked rents into the capital term,

$$\sum_j y_j = H\sum_{ij}\pi_{ij}c_{ij} + (1+\delta_\mu)\,\mathbb{P}\sum_i M_i. \tag{31}$$

Partial land rent capture is therefore equivalent to construction capital being more expensive. In (31), each unit of capital invested in floor space costs the city $1+\delta_\mu$ units of resources. The optimal policy makes occupants face this social cost, and a single city-wide ad valorem rate closes the gap at every block and for both uses.

Seen from the occupants' side, the rate δ_μ is Pigouvian at the margin. Along the developers' supply curve, producing one additional unit of floor space raises the land rents of the block by $\frac{1-\lambda}{\lambda}$ times its price, of which a fraction $(1-\mu)$ accrues to absentee owners and leaves the economy. The optimal tax charges each unit of floor space exactly this marginal leakage. It is the counterpart of the second component of Proposition 1: in the monocentric model the supply of land at each location is fixed, so a location-based tax that reallocates demand is enough to depress rents, whereas here floor space is produced with capital, the leakage arises on the construction margin, and correcting it requires an instrument that reaches the relative price of floor space. This also explains why location-based transfers alone cannot implement the optimum for $\mu < 1$: a transfer that depends only on where a worker lives and works changes incomes but not relative prices, so households continue to equate their marginal rate of substitution to the market price of floor space, while the optimum requires a wedge of exactly $1+\delta_\mu$ between the price occupants face and the price developers receive.

Here "unchanged" refers to functional form: the income tax and the location-based subsidies keep the coefficients of Proposition 3 and carry no term in μ, even though their realized levels move with μ through the equilibrium wages, densities, and outputs that enter them. The floor-space tax is the only instrument that depends on the rent capture share by construction.

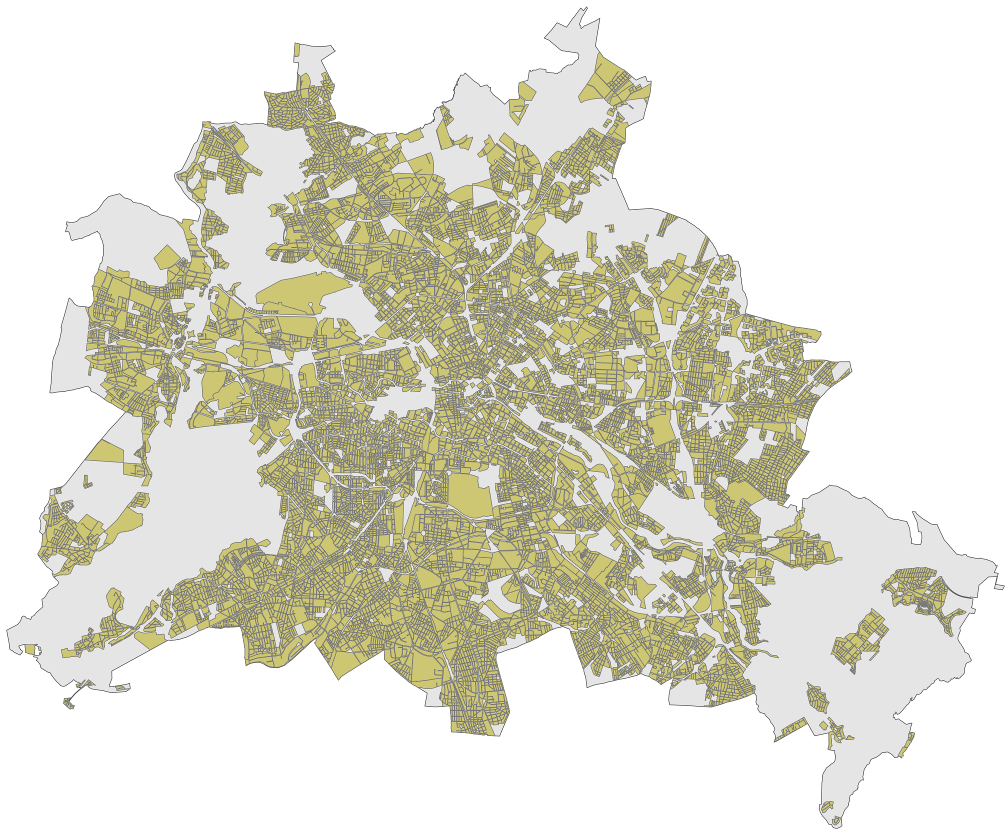
For the Berlin calibration, $\lambda = 0.75$, and therefore the optimal rate is $\delta_\mu = (1-\mu)/3$: a 33 percent tax on the use of floor space when no land rent is captured, falling linearly to zero under full capture. Equivalently, since occupants pay $(1+\delta_\mu)$ times what developers receive, the optimum can be levied on owners as a tax on rental income at rate $\delta_\mu/(1+\delta_\mu)$, which at $\mu = 0$ equals $1-\lambda$, the land share in construction.

4.4 Numerical analysis

We quantify the optimal policy using the parametrization of Berlin in 2006 provided by Ahlfeldt et al. (2015). The city consists of 12,309 statistical blocks (Blöcke). Figure 5 depicts their distribution. The model's parameters are $\alpha = 0.80$, $\beta = 0.75$, $\varepsilon = 6.69$, $\kappa = 0.0148$, $\lambda = 0.75$, $\eta = 0.155$, $\rho = 0.759$, $\lambda_A = 0.071$, and $\delta_A = 0.362$, the pooled estimates reported by the authors, and we set the agricultural rent to zero and the price of capital to one, as they do.

The authors recover the unobserved location characteristics that rationalize the observed data $\{\mathbb{Q}, \boldsymbol{H}_M, \boldsymbol{H}_R, \boldsymbol{t}, \boldsymbol{K}\}$ as an equilibrium of the model. We follow the same strategy: we invert adjusted wages from commuting market clearing and amenities from residential choice probabilities, and we calibrate the productivity and construction fundamentals so that the observed allocation of 2006

Figure 5: Statistical blocks: Berlin.



is exactly the equilibrium of the model with $\mu = 0$ and no taxes.[8]

We evaluate three policy packages at $\mu \in \{0, 0.5, 1\}$: (i) the income tax τ_0 at rate $1/(1+\varepsilon)$ alone; (ii) τ_0 plus the agglomeration subsidies τ_1, residential and workplace, that is, the instrument of Proposition 3, which is optimal only under full capture; and (iii) the optimal policy of Proposition 4, which adds the property tax at the closed-form rate $\delta_\mu = (1-\mu)/3$. In all cases the revenue is rebated lump sum. The fundamentals are those of the baseline calibration at every capture share. Table 3 reports expected utility, the utility gain relative to scenario (i), and aggregate land rents.

Three results follow. First, policy (iii) dominates the instrument of Proposition 3 at every $\mu < 1$, and the gap scales with the share of rents that leaks: at $\mu = 0$, adding δ_μ contributes $+2.29$ percentage points on top of the income tax and the subsidies. Second, at $\mu = 1$ the property tax vanishes and scenario (iii) coincides with (ii), as Proposition 4 requires. Third, the mechanism is visible in land rents: the agglomeration subsidies alone increase aggregate rents by about 9

[8] Since the scale parameters $\boldsymbol{T}$ and $\boldsymbol{E}$ enter the model isomorphically with amenities and wages, we work with the standard composites and normalize the workplace scales to one. The policy rankings and welfare gains reported below do not depend on this normalization: recomputing the main scenarios at $\mu = 0$ with workplace scales drawn from a uniform distribution, and with the scales set equal to the adjusted wages, changes the gain of the agglomeration subsidies relative to the income tax by less than 0.25 percentage points, and the gain of the optimal policy relative to the subsidies by less than 0.15 percentage points.

Table 3: Optimal policy in the quantitative model: income tax (i), adding the agglomeration subsidy (ii), and adding the closed-form property tax (iii).

μ	0			0.5			1		
Instrument	(i)	(ii)	(iii)	(i)	(ii)	(iii)	(i)	(ii)	(iii)
δ_μ [%]	-	-	33.3	-	-	16.7	-	-	0
$\overline{U}$	12.484	13.079	13.364	13.265	13.920	14.009	14.076	14.792	14.792
Relative efficiency	-	+4.76%	+7.05%	-	+4.94%	+5.61%	-	+5.09%	+5.09%
Aggregate land rents R	358,562	389,626	280,660	361,006	391,258	328,402	364,425	393,702	393,702

Notes: Relative efficiency is the utility gain over scenario (i) at the same μ. The property-tax rate δ_μ is the closed form of Proposition 4.

percent, worsening the leakage, while the optimal instrument reduces them by 22 percent at $\mu = 0$ and 9 percent at $\mu = 0.5$. This is the same indirect transfer from absentee landlords to residents that drives the monocentric results of Section 3: the optimal city uses less floor space at lower prices, so it is, on average, less dense than the market allocation despite the positive agglomeration externalities. Figures 6 and 7, the counterpart in Berlin of Figures 2 and 3, make this concrete: with the city's land ordered from densest to least dense, and from highest to lowest priced, the optimal policy lies below the market across nearly all of the land, in both floor-space density and net floor price. The reduction is broad rather than concentrated in a few blocks: the optimal city is a sparser and cheaper version of the market city almost everywhere, as in the case of the monocentric city. Figure 8 maps the marginal contribution of the property tax at $\mu = 0$, comparing scenario (iii) with scenario (ii). Net floor prices fall in more than four of every five blocks, with a median decline of 4.6 percent, while residents reallocate modestly toward cheaper blocks: the welfare gain operates mainly through lower land values rather than through relocation.

4.4.1 Second-best instruments

The optimal instrument of Proposition 4 taxes both uses of floor space at a common rate and operates alongside the Fréchet income tax and the agglomeration subsidies. Yet most property taxes in practice exempt commercial floor space, and the property tax is often the only instrument of the package that a city government controls. We quantify the cost of these two departures, and of the naive policy of subsidizing agglomeration alone.

A property tax that exempts commercial floor space attains at best $+0.93$ percent over scenario (ii) at $\mu = 0$, capturing only 43% of the full $+2.18$ percent gain over the same scenario that the property-tax component delivers when both uses are taxed: commercial floor space generates land rents, and leakage, on the same terms as housing. A property tax used alone, with neither the income tax nor the subsidies, improves welfare by $+2.76$% over the zero-policy equilibrium with an optimal rate near 0.40, above the closed form, because the single instrument partially substitutes for the missing income-tax correction. When the income tax is in place, the optimal property-tax

Figure 6: Floor-space density in Berlin at $\mu = 0$: market allocation versus optimal policy (iii), with land ordered densest first.

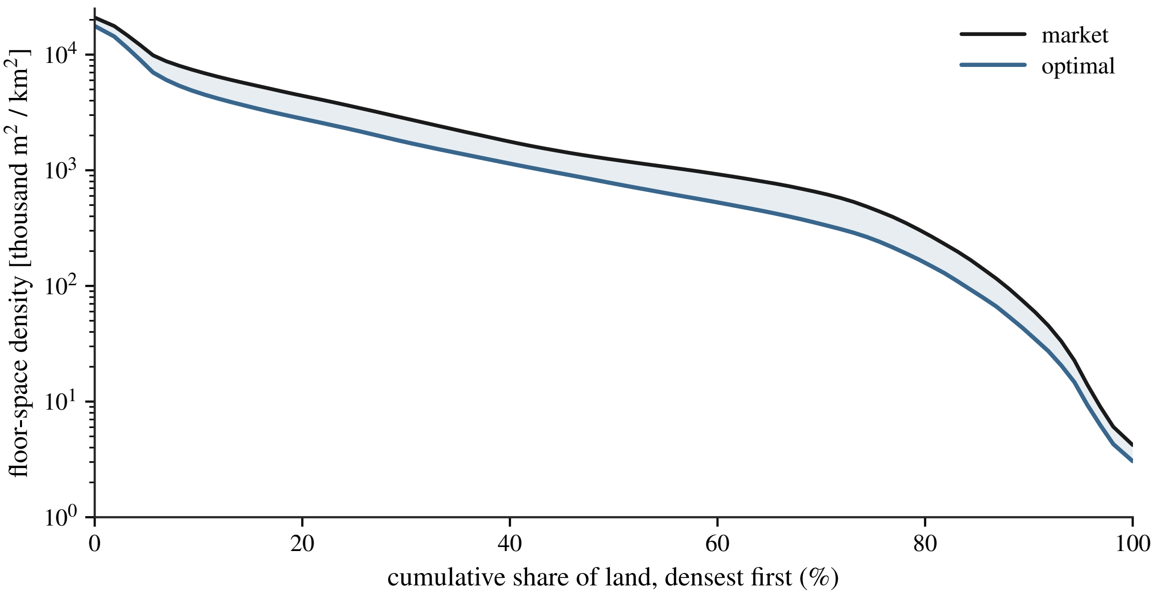


Figure 7: Net floor price in Berlin at $\mu = 0$: market allocation versus optimal policy (iii), with land ordered highest-priced first.

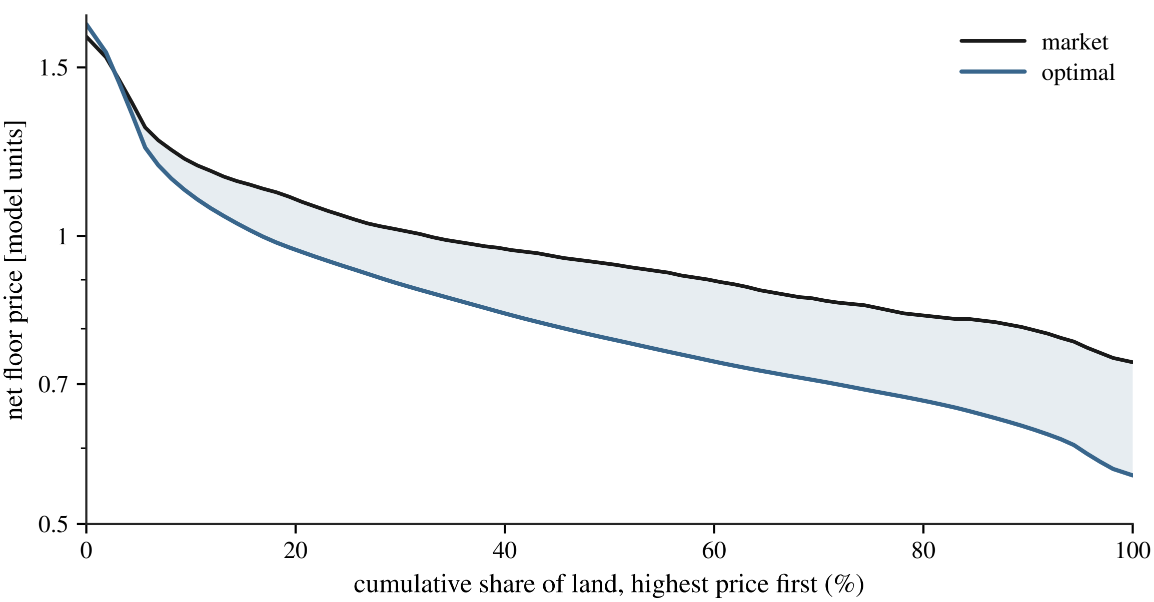
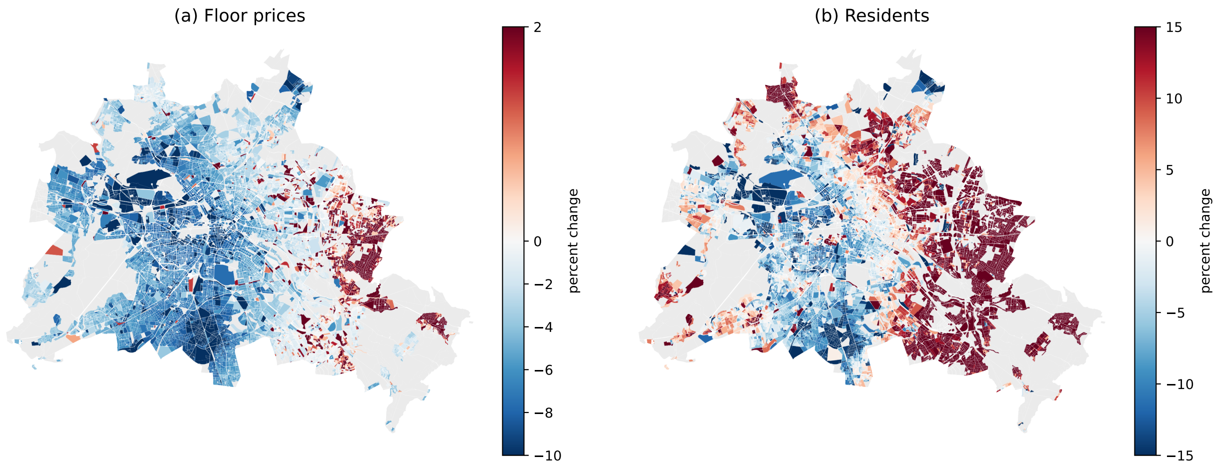


Figure 8: Marginal effect of the property tax δ_μ at $\mu = 0$: block-level percentage change in net floor prices (left) and in residents (right), scenario (iii) relative to scenario (ii).



rate returns to δ_μ. Finally, the agglomeration subsidies used alone, the counterpart of the naive Pigouvian policy of Section 3, raise utility by $+4.57\%$ over the zero-policy equilibrium at $\mu = 0$, while raising aggregate land rents by 8 percent. This is 55 percent of the $+8.32\%$ that the optimal policy attains over the same benchmark, and the share rises to 73 percent at $\mu = 0.5$ and 88 percent under full capture: the gain that the subsidies leave on the table grows with the leaked share of rents. Unlike in the monocentric quantification, the subsidies alone do not lower utility, because the estimated externalities of Berlin are much stronger than the meta-analysis elasticity used there.

4.4.2 Optimal density across capture shares and externality strengths

We close the quantitative analysis by mapping the answer to the paper's central question. We vary the capture share $\mu \in \{0, 0.25, 0.5, 0.75, 1\}$ and the amenity externality elasticity η from zero up to the largest value at which the model returns a single equilibrium. For each η we recalibrate the amenity fundamentals so that the observed city remains the zero-policy equilibrium at $\mu = 0$. The inversion recovers the total amenity of each block, and the fundamental is the part of that total not generated by the observed density at elasticity η: a higher η attributes more of each block's amenity to its density and less to its fundamentals, leaving the observed equilibrium unchanged. The fundamentals do not vary with μ, so each row of Figure 9 compares capture shares within the same economy, and at positive capture shares the market city is the equilibrium response of this economy to the rebated rents, not the observed allocation. At each (μ, η) we solve the market equilibrium and the optimal-policy equilibrium of Proposition 4 and compare their density. Figure 9 reports the change in aggregate floor space.

Every cell is negative: the optimal city uses less floor space than the market city at every

Figure 9: Optimal versus market density in the Berlin model, across capture shares and externality strengths. Each cell is the percentage change in aggregate floor space under the optimal policy relative to the market equilibrium at the same (μ, η).

capture share and every externality strength shown, with reductions ranging from 1 percent under full capture and no amenity externalities to 30 percent under no capture at the estimated elasticity, the outlined row of Figure 9. The gap narrows as the captured share rises, because the property tax rate falls with μ, and widens as the externality strengthens. Within the region shown, solving from several dispersed starting points always returns the same equilibrium. For elasticities beyond those shown different starting points converge to different equilibria, and for stronger externalities still the solution algorithm no longer converges, so the model stops delivering well-defined policy comparisons. Within the region where it does, the case for densification does not arise.

This answer does not rest on the production externality or on the interaction of the two agglomeration forces. Repeating the entire exercise with the production externality switched off, so that the residential amenity externality is the only endogenous force, moves each cell of Figure 9 by less than three percentage points, with the estimated-elasticity row again between 11 and 30 percent below the market level, and the closed form and the exact nesting at full capture are unchanged. The capture margin, not the externality structure, drives the answer.

5 Conclusions

This paper asks whether cities should be denser when a share of the land rents is not captured and redistributed among residents. The share that accrues to absentee owners leaves the economy, so the competition for central locations transfers resources out of the city, and this leakage is a dispersion force that spatial policy must correct alongside the agglomeration externalities. Under realistic ownership structures, it reverses the usual prescription: the optimal city is less dense than the market city, and the policy that the welfare case supports is not a density subsidy but a tax on the rents that density creates.

In the monocentric city model, the tax schedule that maximizes equilibrium utility adds to the Pigouvian subsidy a component proportional to the expenditure on housing and to the share of rents that is not captured. Under mild conditions this component decreases with the distance to the center, so it taxes central locations and, net of the lump-sum rebate, subsidizes peripheral ones, and the resulting city is more extended than the market allocation. In a quantification with United States parameters, the optimal city is up to 32 percent longer than the market city, and implementing the Pigouvian subsidy alone reduces equilibrium utility for most values of the captured share: when land rent capture is partial, the scope for agglomeration instruments is narrower than the externality alone suggests.

In the quantitative model of Berlin, we derive the optimal policy in closed form for any capture share. The income tax and the agglomeration subsidies that are optimal under full capture remain unchanged, and the entire dependence on land rent capture operates through an ad valorem tax on residential and commercial floor space at rate $(1-\mu)(1-\lambda)/\lambda$, which charges each unit of floor space the marginal land rent that its construction generates for absentee owners. At the Berlin calibration the optimal rate is one third of the floor price under an absentee landlord and zero land rent capture, equivalent to a tax on rental income at the land share in construction, and the policy raises welfare by up to 7.1 percent relative to the income tax alone while reducing aggregate land rents by more than a fifth. The structure of the tax matters as much as its level: exempting commercial floor space, the most common design in practice, forgoes 57 percent of the property-tax gain. Mapping the comparison across capture shares and externality strengths, the optimal city uses less floor space than the market city in every configuration in which the model returns a single equilibrium. Overturning this would require amenity spillovers far stronger than the empirical estimates available.

The results have two implications for policy. First, a tax on land rents, with its revenue then being redistributed, and a tax on floor space are explicit substitutes: the optimal property-tax rate falls linearly to zero as the captured share of rents rises to one. Where taxing land rents directly is feasible, it is the better instrument, since it is not distortionary. The property tax is the second-best response to its incompleteness. Residents gain and absentee owners lose, because the tax works by depressing the rents that would otherwise leave the city. Implementation requires no new machinery: property taxes are among the most common instruments in practice, and the departure that matters is taxing commercial floor space at the same rate as housing. Second, the welfare evaluation of urban policies depends on the ownership assumption in a first-order way. An agglomeration subsidy evaluated under collective ownership appears unambiguously beneficial, while under partial capture it raises the rents that leak out of the economy, and a substantial part of the attainable welfare gain comes from an instrument that standard evaluations do not consider. The same caution applies to the assessment of interventions such as transportation investments, whose measured benefits include an indirect land rent transfer that depends on who owns the land.

Two caveats deserve mention, although we do not believe the qualitative conclusions would change. For a fully closed welfare analysis, one might want the landlords to reside in the city and spend their rents in it. The leakage then takes a distributional form: the competition for central land transfers income from renters to owners with a lower marginal utility of income, and a utilitarian planner counts part of that transfer as lost welfare, as if the capture share were interior. Such a planner would still tax the rents that density creates, and still from the center toward the periphery when the landlords, as the higher-income group, occupy the inner city (Duranton and Puga, 2015). Making this precise requires household heterogeneity: our formal analysis concerns the rents that leave the economy altogether. A second caveat concerns the construction technology: the closed form of the optimal property tax relies on the Cobb-Douglas form in (20), under which the rate is a constant. With a block-specific capital share the same argument yields a block-specific rate, and with a general constant-returns technology the rate varies with the equilibrium. In all cases the instrument remains an ad valorem tax on floor space that charges the marginal rent leakage.

Three questions lie beyond this framework. First, the capture share is a primitive here, but over longer horizons it is an outcome: property taxes are set by governments that answer to owners and renters, so the political economy of rent capture determines where actual cities sit on our maps. Second, the analysis is static, while the leakage operates on an investment margin. In a dynamic model with durable buildings and land sales, part of the future leakage is capitalized into today's land prices, so the burden of the corrective tax falls on whoever owns the land when it is announced, and the transition matters as much as the steady state. Third, welfare evaluations of transportation and place-based policies could report the rent transfers they induce alongside the direct benefits, which requires knowing who owns urban land, block by block, a measurement that ownership registries are only beginning to allow.

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Appendices

A Proof of Proposition 1

For this proof, u is twice continuously differentiable, strictly increasing and strongly quasi-concave, both goods are normal, and the commuting cost per mile is the constant t. Strong quasi-concavity is the positivity of the bordered Hessian determinant at every bundle,

$$N(c,l) \equiv 2u_c u_l u_{cl} - u_l^2 u_{cc} - u_c^2 u_{ll} > 0. \tag{32}$$

Households optimize on the intensive margin, constraint (3d) of problem (P), so $Q(x) = u_l/u_c$ holds at every location.

We first record a pointwise identity from consumer theory that is used at the end of the proof. Unlike the constant-utility argument available in the model without externalities, it holds at every bundle, whether or not utility varies across locations.

Lemma 1. *Fix a bundle (c,l) with $Q = u_l/u_c$, let $l^h(Q,\bar{u})$ denote the Hicksian demand for floor space, and let $\sigma = \frac{\partial l^h}{\partial Q}\frac{Q}{l} < 0$ be the income-compensated price elasticity of the demand for housing at that bundle. Then $N(c,l)/u_c^3 = Q/(l\,|\sigma|)$.*

Proof. Differentiate the Hicksian system $u(c,l)=\bar{u}$, $u_l/u_c=Q$ with respect to Q. The first equation gives $u_c\,dc+u_l\,dl=0$, so $dc=-(u_l/u_c)dl$. Differentiating the second,

$$dQ=\frac{dc\,(u_cu_{lc}-u_lu_{cc})+dl\,(u_cu_{ll}-u_lu_{cl})}{u_c^2},$$

and substituting $dc=-(u_l/u_c)dl$ and collecting terms yields $dQ=-dl\,N/u_c^3$. Hence $\partial l^h/\partial Q=-u_c^3/N<0$ and $|\sigma|=(u_c^3/N)(Q/l)$, which rearranges to the claim. $\square$

We first reduce the pointwise budget constraints to a single aggregate one. Let $M\equiv y+\mu R/H+G/H$ denote full income. From the budget constraint, $Q(x)=(M-tx-\tau(x)-c(x))/l(x)$. Substituting the definitions of R and G into M and using $\mu(Q-Q_a)=Q-\mu Q_a-(1-\mu)Q$,

$$M=y+\frac{1}{H}\int_0^{\bar{x}}\Big(Q-\mu Q_a-(1-\mu)Q\Big)dx+\frac{1}{H}\int_0^{\bar{x}}\frac{\tau}{l}\,dx.$$

Replacing the first Q by $(M-tx-\tau-c)/l$, so that the τ terms cancel and $\int(M/l)dx=MH$, and replacing the remaining $(1-\mu)Q$ by $(1-\mu)u_l/u_c$, which is the households' intensive-margin optimality condition, the pointwise budgets collapse to the single aggregate constraint

$$\int_0^{\bar{x}}\left[\frac{tx+c(x)}{l(x)}+\mu Q_a+(1-\mu)\frac{u_l}{u_c}\right]dx=Hy. \tag{33}$$

The planner's problem is therefore

$$(\tilde{P})\quad \max\int_0^{\bar{x}}\frac{\overline{U}}{l}\,dx\quad \text{s.t.}\quad B(1/l)\,u(c,l)=\overline{U}\ \ \forall x,\quad \int_0^{\bar{x}}\Big[\frac{tx+c}{l}+\mu Q_a+(1-\mu)\frac{u_l}{u_c}\Big]dx=Hy,$$
$$\int_0^{\bar{x}}\frac{1}{l}\,dx=H,\qquad \frac{u_l}{u_c}\Big|_{x=\bar{x}}=Q_a,$$

with controls $(c(x),l(x))$ and control parameters $(\overline{U},\bar{x})$. By the population constraint the objective equals $H\overline{U}$, so $(\tilde{P})$ maximizes equilibrium utility. The final constraint is the boundary condition for decentralization. It carries a point multiplier that affects only the optimality condition for $\bar{x}$, which is not needed for the form of $\tau(\cdot)$ and is omitted.

To characterize the optimum, write the pointwise Lagrangian with multipliers $\nu(x)$ (spatial mobility), ψ (aggregate budget), and ϑ (population):

$$\mathscr{L}=\frac{\overline{U}}{l}+\nu\big(B(1/l)u-\overline{U}\big)-\psi\Big[\frac{tx+c}{l}+\mu Q_a+(1-\mu)\frac{u_l}{u_c}\Big]-\frac{\vartheta}{l}.$$

Define

$$\Omega\equiv\psi\,\frac{1-\mu}{u_c^2}\,(u_{cl}u_c-u_lu_{cc}),\qquad \Lambda\equiv\psi\,\frac{1-\mu}{u_c^2}\,(u_{ll}u_c-u_lu_{cl}).$$

The conditions $\partial\mathscr{L}/\partial c = 0$ and $\partial\mathscr{L}/\partial l = 0$ read

$$\nu B u_c = \frac{\psi}{l} + \Omega, \tag{34}$$

$$\nu B u_l = \frac{\overline{U} + \nu B' u - \psi(tx + c) - \vartheta}{l^2} + \Lambda, \tag{35}$$

together with $\int_0^{\overline{x}} \nu\, dx = H$ from the condition for $\overline{U}$.

Finally, dividing (35) by (34) and using $u_l/u_c = Q$,

$$\psi\,(c + Ql) = \overline{U} - \vartheta - \psi\, tx + \nu B' u - l^2\big(Q\Omega - \Lambda\big).$$

Substituting the budget $\tau = M - tx - c - Ql$, the terms in tx cancel and

$$\tau(x) = \Big[M - \tfrac{\overline{U} - \vartheta}{\psi}\Big] - \frac{\nu(x) B' u}{\psi} + l^2\, \frac{Q\Omega - \Lambda}{\psi}. \tag{36}$$

The bracketed term does not depend on x, and adding a constant to τ leaves the decentralized allocation unchanged because it is returned through G/H. We therefore normalize it to zero. The second term is the marginal external benefit of agglomeration, $MEB(x) \equiv \nu(x) B' u/\psi$. When $\mu = 1$, (34) gives $\nu = \psi/(lBu_c)$ and MEB reduces to the familiar expression $nB'u/(Bu_c)$. Direct computation gives

$$\frac{Q\Omega - \Lambda}{\psi} = \frac{1 - \mu}{u_c^3}\Big[u_l(u_{cl}u_c - u_l u_{cc}) - u_c(u_{ll}u_c - u_l u_{cl})\Big] = (1 - \mu)\,\frac{N}{u_c^3} \;\geq 0, \tag{37}$$

with strict inequality for $\mu < 1$ by (32). In particular, the market equilibrium ($\tau \equiv 0$) violates the first-order conditions whenever $\mu < 1$ in the absence of externalities, and the tax reduces to $-MEB$ when $\mu = 1$. Applying Lemma 1 to (37),

$$l^2\, \frac{Q\Omega - \Lambda}{\psi} = (1 - \mu)\, l^2\, \frac{N}{u_c^3} = (1 - \mu)\, \frac{Q\, l}{|\sigma|},$$

which is the second component of the tax, and the statement of Proposition 1 follows. □

B Proof of Proposition 2

Throughout this proof $B \equiv 1$, so the optimal tax is $\tau = \tau_2$. Along an equilibrium, $u(c, l) = \overline{U}$ implies $l(x) = l^h(Q(x), \overline{U})$ and $c(x) = c^h(Q(x), \overline{U})$, so consumption, housing, and the elasticity $|\sigma|$ depend on x only through the local price $Q(x)$. Define $\mathscr{T}(Q) \equiv (1 - \mu)\, Q\, l^h(Q, \overline{U})/|\sigma(Q)|$, so that $\tau_2(x) = \mathscr{T}(Q(x))$.

Consider parts (a) and (b). Differentiating $\mathscr{T}$,

$$\mathscr{T}'(Q) = (1-\mu)\left[\frac{l\,(1+\sigma)}{|\sigma|} + Q\,l\,\frac{d}{dQ}\frac{1}{|\sigma|}\right] > 0,$$

since $\sigma > -1$ makes the first term strictly positive and $|\sigma|$ non-increasing in Q makes the second non-negative. Here we used the expenditure derivative $(Ql^h)' = l^h(1+\sigma)$. The Muth-Mills condition in the taxed equilibrium is $Q' = -(t+\tau_2')/l$ with $\tau_2'(x) = \mathscr{T}'(Q(x))Q'(x)$. Solving,

$$Q'(x) = \frac{-t}{l(x) + \mathscr{T}'(Q(x))} < 0,$$

which is (a), and then $\tau_2' = \mathscr{T}'Q' < 0$, which is (b). For Cobb-Douglas utility $|\sigma| = 1-\beta$ is constant. For CES utility with $\rho < 0$, direct computation gives

$$|\sigma(Q)| = \frac{s}{1+\left(\frac{\beta}{1-\beta}\right)^s Q^{1-s}}, \qquad s = \frac{1}{1-\rho} < 1,$$

which is decreasing in Q, and $\sigma \in (-1,0)$. In both cases the conditions hold.

We turn to part (c). Superscripts m and τ denote the market and taxed equilibria, and $\overline{U}^\tau > \overline{U}^m$ by hypothesis. Floor space is a normal good by hypothesis, as it is for the Cobb-Douglas and CES classes above, so along each equilibrium the Hicksian demand $l(x) = l^h(Q(x),\overline{U})$ is decreasing in the local price and increasing in the utility level.

At the center the taxed price is lower. Integrating the Muth-Mills conditions over each city and using $\int n\,dx = H$ and $Q(\bar{x}) = Q_a$,

$$Q^m(0) = Q_a + Ht, \qquad Q^\tau(0) = Q_a + Ht + \int_0^{\bar{x}^\tau} \tau_2'(x)\,n^\tau(x)\,dx < Q^m(0),$$

where the inequality uses $\tau_2' < 0$ from part (b).

Suppose, toward a contradiction, that $\bar{x}^\tau \le \bar{x}^m$, so both equilibria are defined on $[0,\bar{x}^\tau]$, and let $D \equiv Q^\tau - Q^m$. We first show that $Q^\tau \le Q^m$ on this common domain. At the endpoints $D \le 0$: $D(0) < 0$ since $Q^\tau(0) < Q^m(0)$, and $D(\bar{x}^\tau) = Q_a - Q^m(\bar{x}^\tau) \le 0$ because Q^m is decreasing by part (a) and $\bar{x}^\tau \le \bar{x}^m$. At any point where $D = 0$ the two prices share a common value Q, and since $\overline{U}^\tau > \overline{U}^m$ and floor space is normal, $l^\tau = l^h(Q,\overline{U}^\tau) \ge l^h(Q,\overline{U}^m) = l^m$. The Muth-Mills slopes then give

$$D' = -\frac{t+\tau_2'}{l^\tau} + \frac{t}{l^m} \;\ge\; -\frac{t+\tau_2'}{l^\tau} + \frac{t}{l^\tau} = \frac{-\tau_2'}{l^\tau} > 0,$$

where the first inequality uses $l^\tau \ge l^m$ and the last uses $\tau_2' < 0$. Thus D has strictly positive slope at each of its zeros, so it can cross zero only from below. Since $D(0) < 0$, once D became positive it could never return to zero, which would contradict $D(\bar{x}^\tau) \le 0$. Hence $D \le 0$ throughout $[0, \bar{x}^\tau]$.

Still under this supposition, $Q^\tau \le Q^m$ on $[0, \bar{x}^\tau]$, so a lower price and a higher utility level both raise compensated demand and $l^\tau(x) = l^h(Q^\tau(x), \overline{U}^\tau) \ge l^h(Q^m(x), \overline{U}^m) = l^m(x)$, strictly near 0 where $Q^\tau(0) < Q^m(0)$. Therefore

$$H = \int_0^{\bar{x}^\tau} \frac{dx}{l^\tau} < \int_0^{\bar{x}^\tau} \frac{dx}{l^m} \le \int_0^{\bar{x}^m} \frac{dx}{l^m} = H,$$

where the first inequality is strict because $l^\tau \ge l^m$ with strict inequality near 0, and the second holds because $1/l^m \ge 0$ and $\bar{x}^\tau \le \bar{x}^m$. This contradiction rules out $\bar{x}^\tau \le \bar{x}^m$, so $\bar{x}^\tau > \bar{x}^m$. □

C Proof of Propositions 3 and 4

We prove Proposition 4. Proposition 3 is the special case $\mu = 1$, in which the property tax vanishes. A policy consists of location-based transfers τ_{rs} and taxes on the use of floor space that may differ across blocks and between uses: occupants pay the gross prices $\tilde{Q}_i$ and $\tilde{q}_j$, and developers receive the net prices Q_i and q_j. All tax revenue and the captured rents $\mu \sum_i R_i$ are rebated lump sum, and the scale parameters are normalized, $T_i = E_j = 1$. Heterogeneous scales multiply the sorting constraint below by pair-specific constants and change nothing in the argument. Productivity is endogenous through (15), so block output is $y_s = A_s(\boldsymbol{H}_M) H_{Ms}^{\alpha} L_{Ms}^{1-\alpha}$, and firms take A_s as given. Setting $\lambda_A = 0$ removes every production-externality term below and yields the amenity-only version of the results. We first derive the constraints that the equilibrium allocation satisfies under any such policy (Lemmas 2 and 3), then solve the planner's program of maximizing expected utility subject to them, and finally decentralize its solution.

Lemma 2. *In any equilibrium, at every block, with $L_i = L_{Ri} + L_{Mi}$ the block's total floor space and $\mathscr{Q}_i$ its net floor price,*

$$\mathbb{P} M_i = \lambda\, \mathscr{Q}_i L_i, \qquad R_i = (1-\lambda)\, \mathscr{Q}_i L_i = \frac{1-\lambda}{\lambda}\, \mathbb{P} M_i, \qquad \mathscr{Q}_i = \mathbb{P} \mathscr{M}_i'(L_i),$$

where $\mathscr{M}_i(L) \equiv L^{1/\lambda} K_i^{-(1-\lambda)/\lambda}$ is the capital requirement.

Proof. The developer solves $\max_M \mathscr{Q} L(M) - \mathbb{P} M - \mathbb{R} K$ with $L = M^\lambda K^{1-\lambda}$ and K fixed. The capital condition gives $\mathbb{P} = \lambda \mathscr{Q} L / M$, and the land price absorbs the residual under constant returns, $\mathbb{R} K = (1-\lambda)\mathscr{Q} L$. Since K is fixed, delivering L requires exactly $M = \mathscr{M}_i(L)$, and the supply price is $\mathscr{Q} = \mathbb{P} \mathscr{M}_i'(L)$. Where both uses are active the net prices coincide, $Q_i = q_i = \mathscr{Q}_i$, because developers supply floor space to the use with the higher net price. □

Lemma 3. *In any equilibrium, regardless of the policy,*

$$\sum_{rs} H_{rs}c_{rs} + \mathbb{P}\sum_i M_i + (1-\mu)\sum_i R_i = \sum_s y_s. \tag{38}$$

Consequently, using Lemma 2, on the set of equilibrium allocations the resource constraint reads

$$\sum_{rs} H_{rs}c_{rs} + \kappa_\mu \mathbb{P}\sum_i \mathscr{M}_i(L_{Ri}+L_{Mi}) = \sum_s y_s, \qquad \kappa_\mu \equiv 1+(1-\mu)\frac{1-\lambda}{\lambda}. \tag{39}$$

Proof. We aggregate the budget constraints of workers, the government, firms, and developers, using the market-clearing conditions at each step.

Workers. A worker living in r and working in s spends her disposable income on consumption and on housing at the gross price,

$$c_{rs} + \tilde{Q}_r l_{rs} = w_s - \tau_{rs} + I. \tag{40}$$

We sum (40) over all workers, that is, over every pair (r,s) with weights H_{rs}. On the left-hand side, the housing term aggregates to $\sum_{r,s} H_{rs}\tilde{Q}_r l_{rs} = \sum_r \tilde{Q}_r L_{Rr}$ by residential market clearing, $L_{Rr} = \sum_s H_{rs}l_{rs}$. On the right-hand side, the wage term aggregates to $\sum_{r,s} H_{rs}w_s = \sum_s w_s H_{Ms}$ by labor market clearing, $H_{Ms} = \sum_r H_{rs}$, and the transfer term adds up to HI because $\sum_{r,s} H_{rs} = H$. The result is:

$$\sum_{r,s} H_{rs}c_{rs} + \sum_r \tilde{Q}_r L_{Rr} = \sum_s w_s H_{Ms} - \sum_{r,s} H_{rs}\tau_{rs} + HI. \tag{41}$$

Government. The transfer returns to workers all the tax revenue, from the location-based taxes and from the floor-space taxes on both uses, plus the captured share of the land rents:

$$HI = \sum_{r,s} H_{rs}\tau_{rs} + \sum_r \left(\tilde{Q}_r - Q_r\right)L_{Rr} + \sum_s \left(\tilde{q}_s - q_s\right)L_{Ms} + \mu\sum_i R_i. \tag{42}$$

Firms. Firms rent commercial floor space at the gross price, so their optimality conditions are $w_s = \alpha y_s/H_{Ms}$ and $\tilde{q}_s = (1-\alpha)y_s/L_{Ms}$. With constant returns, factor payments exhaust output block by block, $y_s = w_s H_{Ms} + \tilde{q}_s L_{Ms}$. Summing over blocks:

$$\sum_s y_s = \sum_s w_s H_{Ms} + \sum_s \tilde{q}_s L_{Ms}. \tag{43}$$

Substituting (42) for HI in (41), the transfer terms $\sum_{r,s} H_{rs}\tau_{rs}$ appear once with each sign and cancel:

$$\sum_{r,s} H_{rs}c_{rs} + \sum_{r} \tilde{Q}_r L_{Rr} = \sum_{s} w_s H_{Ms} + \sum_{r} \left(\tilde{Q}_r - Q_r\right) L_{Rr} + \sum_{s} \left(\tilde{q}_s - q_s\right) L_{Ms} + \mu \sum_{i} R_i.$$

Substituting (43) for the wage bill $\sum_s w_s H_{Ms}$ and solving for output then gives

$$\sum_{s} y_s = \sum_{r,s} H_{rs}c_{rs} + \sum_{r} \tilde{Q}_r L_{Rr} - \sum_{r} \left(\tilde{Q}_r - Q_r\right) L_{Rr} + \sum_{s} \tilde{q}_s L_{Ms} - \sum_{s} \left(\tilde{q}_s - q_s\right) L_{Ms} - \mu \sum_{i} R_i.$$

It follows that

$$\sum_{r,s} H_{rs}c_{rs} + \sum_{r} Q_r L_{Rr} + \sum_{s} q_s L_{Ms} = \sum_{s} y_s + \mu \sum_{i} R_i. \tag{44}$$

Developers. The developers of block i sell its total floor space $L_i = L_{Ri} + L_{Mi}$ at the net price $\mathscr{Q}_i$, and adding the first two equalities of Lemma 2 splits their revenue into capital payments and land rents, $\mathscr{Q}_i L_i = \mathbb{P} M_i + R_i$. An active use pays the block's net price and an inactive use has zero floor space, so $Q_i L_{Ri} = \mathscr{Q}_i L_{Ri}$ and $q_i L_{Mi} = \mathscr{Q}_i L_{Mi}$ at every block. Summing over blocks gives

$$\sum_{r} Q_r L_{Rr} + \sum_{s} q_s L_{Ms} = \mathbb{P} \sum_{i} M_i + \sum_{i} R_i.$$

Substituting this into (44), the rents captured by workers cancel and only the leaked share remains on the cost side, which is (38). Equation (39) then substitutes $R_i = \frac{1-\lambda}{\lambda} \mathbb{P} M_i$ and $M_i = \mathscr{M}_i(L_{Ri} + L_{Mi})$, both from Lemma 2. □

Equation (38) is central to the result. For $\mu < 1$ the leaked rents are a real outflow of resources, so the full-capture resource constraint $\sum_{r,s} H_{rs}c_{rs} + \mathbb{P}\sum_i M_i = \sum_s y_s$ no longer holds. A planner that imposed it anyway would recover the $\mu = 1$ optimum at every μ, so the program below is built on the correct resource constraint (39).

We now set up the planner's program. In any equilibrium, the allocation satisfies three families of restrictions. First, combining the choice probabilities (10) with the expected utility (13) gives the Fréchet sorting condition $\overline{U} = \gamma H_{rs}^{-1/\varepsilon} H^{1/\varepsilon} B_r u_{rs}$ for every pair (r,s): pairs that attract more workers must offer proportionally higher systematic utility. Second, the population and the floor space add up: $\sum_{r,s} H_{rs} = H$, $H_{Rr} = \sum_s H_{rs}$, $H_{Ms} = \sum_r H_{rs}$, and $\sum_s H_{rs} l_{rs} = L_{Rr}$. Third, by Lemma 3, the resource constraint (39) holds. Conversely, we show below that the solution of the program of maximizing $\overline{U}$ subject to these restrictions is implementable by a policy in the class above, so solving it yields the optimum. Absorbing the constant γ into the multipliers, the program is

$$
\begin{array}{lll}
\max \overline{U} \quad \text{s.t.} & \overline{U} = H_{rs}^{-1/\varepsilon} H^{1/\varepsilon} B_r(\boldsymbol{H}_R)\, u_{rs}(c_{rs}, l_{rs}) \quad \forall (r,s) & [A_{rs}] \\
& \sum_{rs} H_{rs} c_{rs} + \kappa_\mu \mathbb{P} \sum_i \mathscr{M}_i(L_{Ri} + L_{Mi}) = \sum_s y_s(\boldsymbol{H}_M, L_{Ms}) & [J] \\
& \sum_s H_{rs} l_{rs} = L_{Rr} & [D_r] \\
& \sum_{rs} H_{rs} = H & [E] \\
& H_{Ms} = \sum_r H_{rs} & [F_s] \\
& H_{Rr} = \sum_s H_{rs} & [I_r]
\end{array}
$$

where u_{rs} denotes the systematic part of (5), which is homogeneous of degree one in (c,l).

Turning to the first-order conditions, those for c_{rs} and l_{rs},

$$
A_{rs} H_{rs}^{-1/\varepsilon - 1} H^{1/\varepsilon} B_r \frac{\partial u_{rs}}{\partial c} = J, \qquad A_{rs} H_{rs}^{-1/\varepsilon - 1} H^{1/\varepsilon} B_r \frac{\partial u_{rs}}{\partial l} = D_r, \tag{45}
$$

are combined as follows. Since u_{rs} is homogeneous of degree one in (c,l), Euler's theorem gives $u_{rs} = c_{rs}\, \partial u_{rs}/\partial c + l_{rs}\, \partial u_{rs}/\partial l$. Multiplying the first condition in (45) by c_{rs}, the second by l_{rs}, and adding:

$$
A_{rs} H_{rs}^{-1/\varepsilon - 1} H^{1/\varepsilon} B_r\, u_{rs} = J\, \tilde{x}_{rs}, \qquad \tilde{x}_{rs} \equiv c_{rs} + \frac{D_r}{J}\, l_{rs}, \tag{46}
$$

and the Cobb-Douglas shares $c_{rs} = \beta \tilde{x}_{rs}$ and $(D_r/J)\, l_{rs} = (1-\beta)\tilde{x}_{rs}$: the shadow consumer price of floor space in r is D_r/J, common across workplaces. The floor-space conditions are

$$
\frac{\partial}{\partial L_{Rr}}: \quad D_r = J\, \kappa_\mu\, \mathbb{P}\, \mathscr{M}_r'(L_{Rr} + L_{Mr}), \qquad \frac{\partial}{\partial L_{Ms}}: \quad (1-\alpha)\frac{y_s}{L_{Ms}} = \kappa_\mu\, \mathbb{P}\, \mathscr{M}_s'(L_{Rs} + L_{Ms}). \tag{47}
$$

For labor, employment in s raises output both privately and through (15): since $\partial A_l / \partial H_{Ms} = \lambda_A A_l\, e^{-\delta_A t_{ls}} / (K_s \Upsilon_l)$,

$$
F_s = J \frac{\partial}{\partial H_{Ms}} \sum_l y_l = J\Big(\alpha \frac{y_s}{H_{Ms}} + e_s\Big) \equiv J\,(w_s + e_s), \qquad e_s = \frac{\lambda_A}{K_s} \sum_l \frac{y_l}{\Upsilon_l}\, e^{-\delta_A t_{ls}},
$$

the private marginal product plus the marginal external product. For H_{rs}, using (46),

$$
-\frac{1}{\varepsilon} J \tilde{x}_{rs} + F_s + I_r - E - J \tilde{x}_{rs} = 0 \quad \Longrightarrow \quad \tilde{x}_{rs} = \frac{\varepsilon}{\varepsilon + 1}\Big(w_s + e_s + \frac{I_r}{J} - \frac{E}{J}\Big),
$$

and for H_{Rr}, using (46) again,

$$
I_r = \sum_{l,s} A_{ls} H_{ls}^{-1/\varepsilon} H^{1/\varepsilon} \frac{\partial B_l}{\partial H_{Rr}} u_{ls} = J \sum_{l,s} \gamma_{lr} \frac{H_{ls} \tilde{x}_{ls}}{H_{Rr}},
$$

with $\gamma_{lr} = \frac{\partial B_l}{\partial H_{Rr}} \frac{H_{Rr}}{B_l}$, which for the amenity specification of the model takes the form stated in Proposition 3.

It remains to decentralize the solution, and the decentralization determines the instruments. Set the net floor price of each block at the developers' supply value, $\mathcal{Q}_i = \mathbb{P}\mathcal{M}_i'(L_{Ri} + L_{Mi})$, common to both uses, and the gross prices at the planner's shadow prices, $\tilde{Q}_r = \kappa_\mu \mathcal{Q}_r$ and $\tilde{q}_s = \kappa_\mu \mathcal{Q}_s$, as (47) requires. The wedge between gross and net prices is the same proportion κ_μ at every block and for both uses, so the floor-space taxes reduce to a single city-wide ad valorem tax at the rate $\delta_\mu = \kappa_\mu - 1 = (1-\mu)\frac{1-\lambda}{\lambda}$ of Proposition 4. Then: (i) the consumer price is $\tilde{Q}_r = \kappa_\mu \mathbb{P}\mathcal{M}_r'(L_{Rr} + L_{Mr}) = D_r/J$, so households with income $\tilde{x}_{rs}$ choose exactly (c_{rs}, l_{rs}); (ii) firms, taking A_s as given at its planned value, face the gross price $\tilde{q}_s$ and satisfy their floor-space condition $(1-\alpha)y_s/L_{Ms} = \tilde{q}_s$ by (47), and the labor market clears at the private wage $w_s = \alpha y_s/H_{Ms}$; (iii) developers, receiving the net prices, supply L_{Rr} and L_{Ms} and generate rents consistent with Lemma 2, so (39) coincides with physical feasibility (38); (iv) setting $\tau_{rs} = w_s - \tilde{x}_{rs} + I$, each worker's disposable income equals $\tilde{x}_{rs}$, the systematic utility at the implemented bundle is $u_{rs} = \tilde{x}_{rs}\tilde{Q}_r^{\beta-1}/d_{rs}$, and the sorting constraint of the planner's program is exactly the Fréchet choice system (10), so workers self-select into the planned allocation; (v) the government budget balances by the construction of I. Substituting the expression for $\tilde{x}_{rs}$ into (iv),

$$\tau_{rs} = \frac{1}{\varepsilon+1} w_s - \frac{\varepsilon}{\varepsilon+1} \sum_{l,s'} \gamma_{lr} \frac{H_{ls'}\tilde{x}_{ls'}}{H_{Rr}} - \frac{\varepsilon}{\varepsilon+1} e_s + C,$$

where the constant C is immaterial because it is returned through the rebate: the optimal package pays each worker the workplace subsidy $\frac{\varepsilon}{\varepsilon+1} e_s$ on top of the residential subsidy, exactly as stated in Proposition 3. Since the wedge κ_μ in (47) is the same at every block and for both uses, and neither e_s nor the residential subsidy depends on μ, a single city-wide rate implements the wedge, which completes the proof. □

D Monocentric profiles over distance to the CBD

Figures 10 and 11 report the floor price and residential density profiles over distance to the CBD at $\mu = 0$ and $\gamma = 0.03$, in three scenarios: no instruments, the agglomeration subsidy τ_1 alone, and the optimal instrument $\tau_1 + \tau_2$. As a reference, both figures also plot the optimal city under full capture ($\mu = 1$). The subsidy alone concentrates the city, raising prices and density at the center. The optimal instrument lowers both at the center and extends the city, so beyond a crossing point its prices and density exceed the market levels at the same location. Figures 2 and 3 compare the same two equilibria rank by rank instead of location by location, matching each city's densest land with the other's. On that comparison the optimal city lies below the market city over the entire land distribution, because the same population and its housing demand are spread over more land.

The reference curve makes a second point: the optimal instrument at $\mu = 0$ approximately reproduces the density profile and the extension of the optimal city under full capture. Unable to return the leaked rents to residents, the planner instead approximates the city that full capture would deliver, so the instrument works as a second best for full land rent capture. Floor prices, and with them consumption and equilibrium utility, do not coincide, because under full capture the recycled rents raise incomes and bid prices up, while at $\mu = 0$ the optimum holds them down.

Figure 10: Floor price profiles at $\gamma = 0.03$: the three $\mu = 0$ scenarios and the optimal city under full capture ($\mu = 1$). The horizontal line is the agricultural rent Q_a.

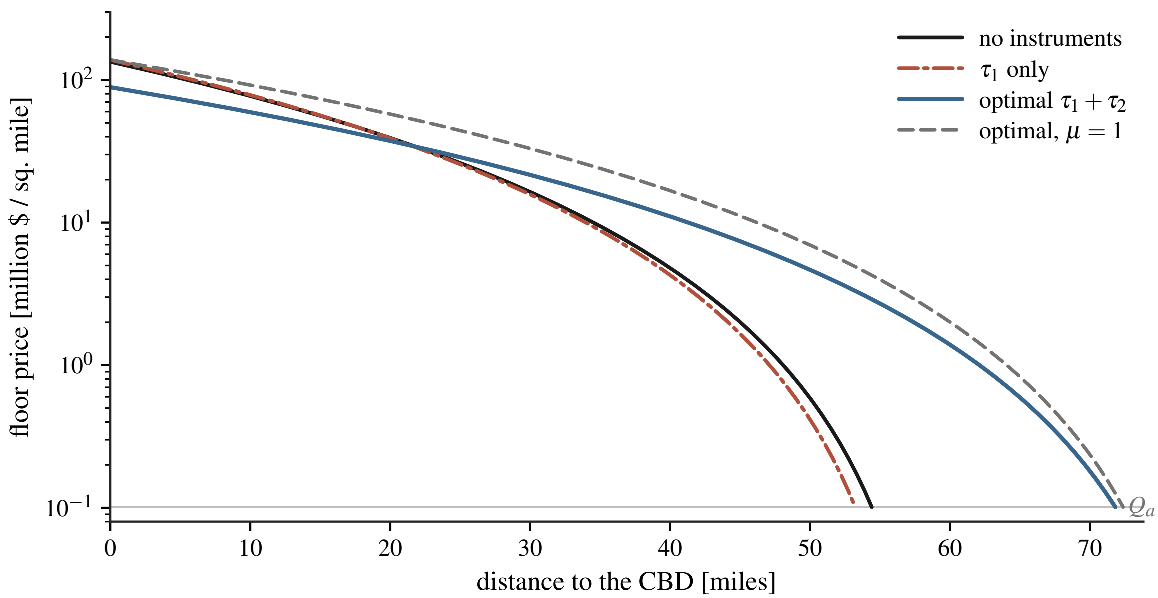

Figure 11: Residential density profiles at $\gamma = 0.03$: the three $\mu = 0$ scenarios and the optimal city under full capture ($\mu = 1$).