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Abstract

Larger cities typically give rise to two opposite effects: tougher competition among firms and higher production costs. Using an urban model with substitutability of production factors and pro-competitive effects, I study the response of the market outcome to city size, land-use regulations, and commuting costs. For industries with low input shares of land, larger cities host more firms setting lower prices whereas for sectors with intermediate land shares larger cities accommodate more firms charging higher prices. Softer land-use regulations and/or lower commuting costs reinforce pro-competitive effects, making larger cities more attractive for residents via lower prices and broader product diversity.

JEL-Codes: L110, L130, R130, R320, R520.

Keywords: land prices, pro-competitive effects, city size, product diversity, land-use regulations.

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1 Introduction

It is well documented that living in large cities is expensive but provides better consumption opportunities (Berry and Waldfogel, 2010; Glaeser *et al.*, 2001; Glaeser *et al.*, 2005a; Schiff, 2014). Large metropolitan areas sustain substantially higher housing prices and feature a broader diversity of goods and services (Glaeser *et al.*, 2005b). However, we know less about product price levels in big cities (Handbury and Weinstein, 2014). In this paper, I show that the interplay between the cost and demand sides is crucial for understanding product price formation and variation in diversity among cities. Indeed, a larger city population corresponds to higher land prices (Combes *et al.*, 2018) which pushes production costs up. At the same time, tougher competition in large cities pushes product prices down. Hence, my goal is to tackle a core question in urban economics – the impact of city size on product prices and diversity. This paper complements seminal works on the role of city size (Henderson, 1974; Abdel-Rahman and Fujita, 1990) in two respects. First, I capture the competition effect stemming from variable markups and, second, I account for space in production by explicitly including land in the cost function.

In my analysis, I focus on service sectors and provide additional insights on the mechanisms leading to agglomeration. Besides sharing, matching, and learning (Duranton and Puga, 2004), variation of relative land intensity in production affects industries' tendency towards agglomeration. Indeed, service sectors with strong benefits from agglomeration effects – professional services, information, insurance, finance – are over-represented in city centers while their land shares are lower than the average in services (Brinkman *et al*., 2015; Duranton *et al*., 2015; Karadi and Koren, 2012). I show that relatively small land shares are another source of concentration. Intuitively, relatively small land shares allow for further benefits from agglomeration, and on top of that, higher firm concentration leads to tougher competition which pushes prices down. In addition, those service industries widely adopted automatization in their production processes during the second half of last century (Bresnahan, 1986).[1] Nowadays, these industries are typically large and their product prices are low in big cities.

[1]These industries likely experienced a decrease in the share of land input when computers replaced paper archives in finance and insurance industries, typesetting machines in printing, and panel boards in the R&D and engineering industries.

On the other side of the spectrum, there are traditional retail, food service (restaurants, cafes), entertainment (cinema, theaters) industries, etc. which benefit less from agglomeration economies but are also well represented in city centers. A common belief is that their location decisions are driven by proximity to consumers (Hotelling, 1929). Those industries are typically more evenly distributed within cities, produce non-tradable goods, and attract consumers locally (Cosman and Schiff, 2019). They also have substantially larger than average land shares which push prices up for enterprises located in large cities and, especially, their centers.

To shed additional light on those issues, I study an urban model featuring pro-competitive effects, where production factors – land and labor – are imperfect substitutes. I show that the production side plays a key role in explaining the differences in prices and product diversity across cities of different sizes. I rely on a one-sector closed city model where all firms share the same cost function. However, I obtain precise conditions on land shares in production, for the industry to demonstrate opposite patterns of prices and product diversity when city size expands. This allows discussing the market response to city size for industries with different land shares and provides micro-foundations for variation of prices among the service sectors mentioned above.

My results show that for industries with small input shares of land, larger cities host more firms which set lower prices; whereas larger cities accommodate more firms charging higher prices in sectors with an intermediate land shares in production. For industries with high input shares of land, larger cities contain fewer firms with higher product prices. These results are in line with the inconclusive evidence about the behavior of product prices in cities of different sizes. The intuition underlying these results is as follows. High land rents in larger cities increase the cost of production (henceforth, production cost effect). For industries with relatively high input shares of land, the production cost effect is strong and overcompensates the competition effect. The latter arises due to pro-competitive effects and the standard market crowding effect (more entrants invite consumers to split their budget across more varieties making the market share of each firm smaller) both working in the same direction. A lower land share in production results in a stronger tendency of larger cities to sustain lower product prices and broader diversity. This suggests a simple and intuitive reason for variation in market outcomes of diverse industries across cities of different sizes. On one hand, firms from relatively land-intensive industries, such as restaurants, theaters, and brick-and-mortar retail, charge higher prices in the centers of big cities. On the other hand, industries with relatively low shares of land (finance, insurance, and professional services) are typically large and prices for their production are low in big cities.

Note, however, that in the presence of pro-competitive effects, firms charge lower markups in larger markets independently of factor intensities. At the same time, firms in relatively land-intensive industries set higher prices due to higher production costs because of higher prices for local inputs in larger cities.

Empirical evidence also suggests that relatively less land-intensive services increase their shares of skilled labor over time which further decreases land shares compared to land-intensive sectors. The latter also have substantially higher shares of low-skilled employees (e.g. porters and cashiers in retail, or servers and bartenders in food service). Indeed, Bresnahan *et al.* (2002) show that firms which adopted information technology tend to use more skilled labor, while Rossi-Hansberg and Sarte (2009) report that job decentralization away from city centers has a larger impact on low-skilled jobs than on skill-intensive and managerial jobs. This evidence also confirms my findings that variation in land rents likely influences industries in different ways, depending on the industry's cost structure. Furthermore, Glaeser and Kahn (2001) report a decreasing share of employment in central cities of US metropolitan areas during the second half of the last century. Thus, a decrease in the relative share of land due to the computerization process, allowed those industries to become more competitive in densely populated city centers.

My setting is flexible enough to study an issue that attracts a lot of attention both in the media and in academic journals, i.e., the impact of land-use regulations on product markets and welfare (Porter, 1995). While residential development regulations have been widely studied (see the survey by Gyourko and Molloy, 2015), here I focus on commercial land-use regulations which may take different forms (Duranton and Puga, 2015). Regulations of this type are shown to have negative consequences. Based on US metropolitan statistical area (MSAs) data between

1983 and 2009, Turner *et al.* (2014) find a highly negative impact of land-use regulations on the value of land and welfare. In the same vein, regulations related to office spaces (Cheshire and Hilber, 2008) and stores (Cheshire *et al.*, 2014) have a negative impact on land rents, variety, and stores' output.[2]

I provide micro-foundations for this empirical evidence and show that relaxing land-use regulation increases welfare through lower product prices and broader variety. To retain tractability, the strength of regulation is modeled in a reduced-form way by employing the elasticity of the central business district (CBD) size with respect to city population. Thus, softer land-use regulations are linked to a higher elasticity of the CBD size with respect to city size. I show that soft regulations lead to lower prices and broader product diversity with city growth for a larger number of industries than in the case of strict regulations. This is a consequence of decreasing production costs via lower land rents induced by an increase in land supply. Thus, relaxing regulations is a potential source for social welfare improvements, in line with the above-mentioned empirical evidence.

I conduct a quantitative exercise to provide an idea of the magnitudes of thresholds for land shares in production such that industries demonstrate different patterns in terms of prices and masses of entrants with city expansion. This provides a rough idea for distinguishing across sectors with different market outcomes. My preferred specification shows that prices are lower and product diversity is broader in larger cities for industries with land shares below 15%. Moreover, for sectors with input shares of land between 15% and 25%, prices are higher in larger cities because the competition effect is dominated by the production cost effect.

To match service sectors with various land shares to different patterns, I compare my quantification results with existing empirical estimates. The average share of land in services is about 13% (Duranton *et al.*, 2015; Karadi and Koren, 2012). For service sectors excluding wholesale, retail, and "entertainment" (restaurants, cafes, cinemas, etc.), the land share is estimated at about 9% (Brinkman *et al.*, 2015), which is much lower than the average. Therefore, the land shares for brick-and-mortar retail and food service industries exceed that average and are likely above 15%.

[2] In addition, Hsieh and Moretti (2015) report that over-regulated cities such as New York, San Francisco, and San Jose make a surprisingly small contribution to the nation's economic growth compared to less regulated cities. Lowering the intensity of regulations would substantially increase US GDP.

In this case, my quantitative findings show that those industries feature higher prices while other sectors like professional services, information, and finance, offer lower prices in larger cities. In other words, the theoretical results are consistent with the empirical evidence, at least in the first approximation.

The previous discussion is related to the average level of land-use regulations across cities. For cities with tighter regulations, the threshold values for different price and industry size patterns gradually increase. For instance, in over-regulated cities (where regulations are 2-3 times as strict as the average), firms belonging to the industries with land shares above 8% set higher prices in larger cities; whereas industries with land shares exceeding 13% are smaller in larger cities. Thus, even industries such as professional services with relatively low land shares of about 8%, may set higher prices in over-regulated large cities.

The rest of the paper is organized as follows. Section 2 develops the model. Section 3 provides an analysis of industries with different cost structures in cities of different sizes. In Section 4, the setting is I extended to examine the case of intermediates and knowledge spillovers. Section 5 concludes.

2 The model

Consider a linear city populated by a mass L of consumers who are uniformly distributed over $(0,\ L]$. The city has one central business district (CBD) at $y = 0$ with S being a measure of the available amount of land within the CBD.[3] Each consumer requires 1 unit of land for housing outside the CBD while firms are located in the CBD. Let $y \in (0,\ L]$ denote the location of a consumer and her distance to the CBD.

I assume the CBD size, measured here by S, is less than proportional to city population L. This assumption is supported by the empirical evidence suggesting that (i) the elasticity of unit land prices in the city center with respect to city population is below 1 (Combes *et al.*, 2018), and (ii) the city size growth usually exceeds the growth of the land area (Pagano and Bowman, 2000). Hence, I focus on the case of a disproportionately smaller CBD size with respect to city

[3] My results are robust to the CBD location in the middle of the line $[-L/2,\ L/2]$.

population. To keep things tractable, I assume that the elasticity of the CBD size with respect to city population is a positive constant $\delta < 1$, i.e. $S = L^{\delta}$. The parameter δ may be viewed as a reduced-form for the intensity of land-use regulations. A larger δ corresponds to softer land-use regulations where the CBD land area is more responsive to city population expansion (e.g., conversion of land from housing to commercial usage in the area surrounding the CBD). I discuss the impacts of land-use regulations in Section 3.2.

I assume a one-sector economy which produces a horizontally differentiated good using two production factors, land and labor. I rely on the monopolistic competition framework without scope economies. Thus, the differentiated good market involves a mass of firms N, each firm produces a single variety, and each variety is produced by a single firm.

I also assume that each consumer owns one unit of labor while land rent is equally redistributed across consumers.[4] As in Voith (1998) and Pflüger and Tabuchi (2010), only producers compete for land within the CBD. Similar to Henderson (1974), consumers commute to the CBD where all jobs are located.

2.1 Preferences and technology

I work with non-CES preferences which allow capturing the competition effect that stems from variable markups. In what follows, I assume that consumers have identical additive preferences given by

$$U(y) = \int_0^N u(x_k(y))\mathrm{d}k, \tag{1}$$

where $x_k(y)$ is the per capita consumption of variety k at location y and u is a thrice differentiable, increasing, and concave function with $u(0) = 0$. CES preferences are a special case of (1), where $u = x_k^{\frac{\sigma}{\sigma-1}}(y)$ with σ being the constant elasticity of substitution among varieties.

I rely on a standard assumption of the urban literature by considering linear commuting costs. Hence, each consumer at location y seeks to maximize her utility (1) subject to the budget constraint

[4] Unlike in Albouy *et al.* (2019), the alternative assumption of absentee land-lords does not alter my results.

$$\int_0^N p_k x_k(y) \mathrm{d}k = w + \frac{S}{L} \cdot r + \frac{1}{L} \cdot \int_0^L z(t) \mathrm{d}t - \tau y - z(y), \tag{2}$$

where w is the wage, r is the land price within the CBD, τ is the unit commuting cost, and $z(y)$ is the housing rent at location y. Consumers earn a salary w while the return on land in the CBD (second term on the right-hand side of (2)) and land rent from housing (third term) are equally distributed across consumers. The last two terms on the right-hand side stand for expenditure on commuting costs and housing. Without loss of generality, I normalize the housing price at the border of the city to zero, $z(L) = 0$.

The first-order condition yields an inverse demand function given by

$$p_k = \frac{u'(x_k(y))}{\lambda(y)}, \tag{3}$$

where $\lambda(y)$ is the Lagrange multiplier of a consumer at location y.

There are different ways to specify a firm's cost function. One common approach in economic geography is to "separate" costs by associating labor with variable costs and other factors (land, capital) with fixed costs (Forslid and Ottaviano, 2003). This strategy drastically simplifies the analysis by fixing the number of firms. However, it also implies trivial variations in the number of firms with city size. Since the purpose of this paper is to investigate the variations in prices and the number of firms with city population, I rely on a homothetic cost function where land and labor are imperfect substitutes in the production process. This assumption implies that the density of workers in office spaces tends to be higher when the office rent increases, which is consistent with empirical evidence (Brinkman *et al.*, 2015). It also implies that both land and labor are included in fixed costs. This seems plausible since a typical service enterprise has an HR department and accounting office which are mostly independent of its size. I thus rely on the Cobb-Douglas cost function over land and labor (Bernard *et al.*, 2007):

$$C(q) = (f + cq) w^{\alpha} r^{1-\alpha}, \tag{4}$$

where $\alpha \in (0,\, 1)$ stands for labor intensity in production, f and c are fixed and marginal costs, and q is firm output. Hence, firm k maximizes profit given by

$$\pi_k = (p_k - cw^{\alpha}r^{1-\alpha})q_k - fw^{\alpha}r^{1-\alpha}. \tag{5}$$

Since total cost functions are identical across firms, I suppress the firm index k and focus on the symmetric equilibrium.

2.2 Equilibrium

To obtain the equilibrium system of equations, I proceed as follows. The balances of land and labor markets

$$S = N \cdot \frac{\partial C(q)}{\partial r} = (1-\alpha)N(f+cq)(r/w)^{-\alpha}, \tag{6}$$

$$L = N \cdot \frac{\partial C(q)}{\partial w} = \alpha N(f+cq)(r/w)^{1-\alpha} \tag{7}$$

yield that the relative land price is

$$\frac{r}{w} = \frac{1-\alpha}{\alpha} \cdot \frac{L}{S}. \tag{8}$$

In what follows, I chose labor as the numeraire, so that $w = 1$. Using $S = L^{\delta}$, (8) takes the form

$$r = \frac{1-\alpha}{\alpha} \cdot L^{1-\delta}. \tag{9}$$

Equation (9) shows that the relative price of land in the CBD is higher in a more populated city since $\delta \in (0,\,1)$. This result captures the empirical observations that land rents increase faster than wage. Indeed, Combes *et al.* (2008) report a wage elasticity of about 0.02-0.03, Tabuchi and Yoshida (2000) find it at about 0.14 while the average elasticity of land prices with respect to city size is about 0.6 (Combes *et al.*, 2018). Thus, population growth implies a greater labor supply which makes land a relatively more scarce resource. This, in turn, increases the land price. Furthermore, the land price increases faster if the production is more land-intensive, i.e.

the smaller α.

The equilibrium condition in the housing market requires consumer expenditure on housing and transportation, $\tau y + z(y)$, to be the same across agents independent of their location. Combining this with the fact that land rent at the edge of the city is zero, we get $\tau y + z(y) = \tau L$. This immediately implies that consumed quantities are independent of consumer location $y \in (0,\, L]$. Thus, I drop the location index y. In the following discussion I will refer to the sum of spendings on housing and transportation as urban costs which increase with both commuting costs τ and city size L. The per capita housing expenditure then takes the form $\frac{1}{L} \cdot \int_0^L z(t)\mathrm{d}t = \tau L/2$. Substituting in the budget constraint (2), I get

$$Npx = 1 + rS/L - \tau L/2 \tag{10}$$

in a symmetric equilibrium.

Plugging the inverse demand (3) into profit function (5), the first-order condition of the producer's problem yields the profit-maximization price

$$p = \frac{c}{1-\varepsilon} \cdot \left(\frac{1-\alpha}{\alpha} \cdot L^{1-\delta} \right)^{1-\alpha}, \tag{11}$$

where I make use of (8). Here ε is the inverse demand elasticity given by

$$\varepsilon \equiv -\frac{xu''(x)}{u'(x)}.$$

The function ε also stands for the relative markup

$$m(x) \equiv \frac{p - cr^{1-\alpha}}{p} = \varepsilon.$$

In the special case of CES preferences, $\varepsilon = 1/\sigma$ is a constant. Parenti *et al.* (2017) show that $1/\varepsilon$ still represents the elasticity of substitution in a setting with a variable ε, which will be useful in the quantification part of the paper (Section 3.4).

The second-order condition for the producer's problem is given by

$$1 - \varepsilon + \eta > 0, \tag{12}$$

where η is the super-elasticity of the inverse demand (Nakamura and Zerom, 2010):

$$\eta = \frac{x\varepsilon'}{\varepsilon}.$$

In this paper, I assume that $\eta > 0$, which implies that the second-order condition holds. Furthermore, $\eta > 0$ is a necessary and sufficient condition for pro-competitive effects, i.e. markups decrease with market size (Zhelobodko *et al.*, 2012).

Using (11) and setting the profit function (5) to zero, I obtain the zero-profit condition

$$\frac{x\varepsilon}{1-\varepsilon} = \frac{f}{cL}, \tag{13}$$

while the market clearing condition is given by

$$q = Lx. \tag{14}$$

Finally, plugging (8) into (10), after simplification, yields

$$N \cdot \frac{cx}{1-\varepsilon} \cdot \left(\frac{1-\alpha}{\alpha} \cdot L^{1-\delta} \right)^{1-\alpha} = \frac{1}{\alpha} - \frac{\tau L}{2}. \tag{15}$$

Therefore, a symmetric free entry equilibrium is a bundle $(r,\, x,\, q,\, N)$ which solves the system of equations (8), (13), (14), and (15).

3 Market outcome and city size

In this section, I study the impact of a larger city size (as measured by its population) on the product market, in particular, on prices and product diversity. Although, firms share the same cost function within a sector, this analysis is applicable to the discussion of the impact of city growth on sectors with different land-labor intensities. Yet, taking into account the properties of technology, I show that industries with different land-labor shares demonstrate different behavior of prices and product diversity with city expansion.

I also apply my analysis to a comparison of the market outcome across cities with different land-use regulations. Industries could demonstrate different patterns depending on the level of these regulations. Indeed, the relative land price (8) is higher in cities with a limited size of the CBD which has an impact on industry's prices (11) and the mass of varieties (15). The obvious reasons preventing the CBD from growing are strong land-use regulations which have been shown to cause negative welfare consequences via high CBD land prices (Cheshire and Hilber, 2008; Turner *et al.*, 2014). I capture the variation in land-use regulations across cities through different values of δ in (9) which induce changes in the relative land price within the CBD. Hence, the relative land price with the corresponding level of land-use regulations is a new force shaping product prices and diversity with city size expansion.

3.1 The role of city size

In this subsection, I investigate how product prices and the mass of firms respond to changes in city size L. First, using (13), I compute the elasticity of individual consumption x with respect to L (see Appendix A for the computational details of this section):

$$\frac{\mathrm{dln}x}{\mathrm{dln}L} = -\frac{1-\varepsilon}{1-\varepsilon+\eta} < 0. \tag{16}$$

The elasticity (16) is negative since $\varepsilon \in (0,\, 1)$ and the denominator is positive due to the second-order condition (12). Note that the inverse relationship between individual per-variety consumption x and market size L is due to "love for variety". Indeed, love for variety allows individuals to reach higher utility levels in larger markets by consuming more varieties in smaller quantities.[5] Furthermore, firm output is larger in bigger cities as

$$\frac{\mathrm{dln}q}{\mathrm{dln}L} = 1 + \frac{\mathrm{dln}x}{\mathrm{dln}L} = \frac{\eta}{1-\varepsilon+\eta} > 0,$$

[5]This result holds for arbitrary additive preferences, including CES where pro-competitive effects disappear.

which is consistent with the empirical evidence (Levinsohn, 1999). However, firms located in bigger cities charge lower markups $m = \varepsilon$ because of the inverse relationship (16) between individual consumption x and city size L and increasing ε.

Taking the elasticity of (11), after simplifications, I obtain the behavior of the product price p with respect to the city size L:

$$\frac{\mathrm{dln}p}{\mathrm{dln}L} = (1-\delta)(1-\alpha) - \frac{\varepsilon\eta}{1-\varepsilon+\eta}, \tag{17}$$

where I make use of (16). As implied by (17), a firm sets higher (lower) prices in a larger city when it belongs to the land (labor)-intensive sectors with $\alpha < \overline{\alpha}$ ($\alpha > \overline{\alpha}$), where $\overline{\alpha}$ is given by

$$\overline{\alpha} = 1 - \frac{1}{1-\delta} \cdot \frac{\varepsilon\eta}{1-\varepsilon+\eta}, \tag{18}$$

where the right-hand side is evaluated at equilibrium. This result is driven by the interplay between two opposite effects: (i) the *production cost effect*, which is due to higher land prices in larger cities captured by (8); and (ii) the standard *competition effect*. The latter is the sum of a market-crowding effect and pro-competitive effects which reduce prices in larger markets. The first effect is missing in the one-factor setting, $\alpha = 1$, where $\mathrm{dln}p/\mathrm{dln}L < 0$ and firms always set lower prices in larger markets.

In an urban setting with factor substitutability, a firm's pricing decision depends on its cost structure. When the industry's production is relatively land-intensive, i.e. $\alpha < \overline{\alpha}$, the competition effect is dominated by the production cost effect. In this case, firms charge higher prices in larger cities, thus *the equilibrium markup and price go in opposite directions*. In other worlds, despite the fact that markups are lower in larger cities in the presence of pro-competitive effects, firms may set higher product prices. This tendency is stronger for firms that belong to land-intensive industries since they are more sensitive to land price. Otherwise, for labor-intensive industries, $\alpha > \overline{\alpha}$, the competition effect dominates the production cost effect and, as a result, firms set lower prices in larger cities.

The mass of firms N given by (15) depends on both city size L and its urban costs τL. Using (15), after simplifications, the elasticity of the mass of firms N with respect to L takes the following form:

$$\frac{\text{dln}N}{\text{dln}L} = 1 - (1-\delta)(1-\alpha) - \frac{(1-\varepsilon)\eta}{1-\varepsilon+\eta} - \frac{\tau L}{\frac{2}{\alpha} - \tau L}. \tag{19}$$

Let $\underline{\alpha}$ be a solution to $\text{dln}N/\text{dln}L = 0$, i.e. $\underline{\alpha}$ is implicitly defined as a solution to

$$\alpha - \frac{1}{1-\delta} \cdot \frac{\tau L}{\frac{2}{\alpha} - \tau L} = \frac{1}{1-\delta} \cdot \left(\frac{(1-\varepsilon)\eta}{1-\varepsilon+\eta} - \delta \right). \tag{20}$$

Hence, a larger city hosts fewer (more) firms in land (labor)-intensive industries, $\alpha < \underline{\alpha}$ ($\alpha > \underline{\alpha}$).[6] The intuition behind this result is in line with the discussion on firms' pricing: larger cities attract fewer firms from relatively land intensive industry, $\alpha < \underline{\alpha}$, because of the production cost effect dominating the competition effect.

In Section 3.4, I show that for empirically relevant values of urban costs τL: (i) the term in parenthesis of (20) is positive, thus, $\underline{\alpha} < 1$; and (ii) for any land share, citizens' welfare decreases with city size (Henderson, 1974). This points to the existence of small cities and provides a rationale for comparison across cities with different sizes (within the current framework). Put it differently, in equilibrium the elasticity of utility $U = Nu(x)$ is

$$\frac{\text{dln}U}{\text{dln}L} = \frac{\text{dln}n}{\text{dln}L} + \frac{\text{dln}u}{\text{dln}x}\frac{\text{dln}x}{\text{dln}L} < 0 \tag{21}$$

for all $\alpha \in (0, 1)$. Consider two cities with arbitrary sizes $L_1 > L_2$. Since cities are on the downward sloping part of welfare curve, there is no reallocation of people between cities. This allows to compare large and small cities in equilibrium.

A comparison between (20) and (18) shows that $\underline{\alpha} < \overline{\alpha}$, at least for empirically plausible levels of urban costs τL and elasticities of land prices δ, which I discuss in Section 3.4. Once we obtain clear-cut results on the behavior of prices and product diversity depending on the land share of a single industry, we are equipped to compare industries with different cost functions. Indeed, there are three different patterns: (i) when $\alpha > \overline{\alpha}$, i.e. the industry is labor intensive, the production cost effect is weak, therefore, larger cities host more firms of this sector setting

[6] In the one-factor setting without space $\alpha = 1$ and $\tau = 0$, the mass of firms is always bigger at larger markets.

lower prices; (ii) for intermediate labor intensities, $\underline{\alpha} < \alpha < \overline{\alpha}$, the production cost effect is stronger, hence, the industry features more firms but higher prices in larger cities; and (iii) for the land-intensive sector, i.e. $\alpha < \underline{\alpha}$, the production cost effect dominates the competition effect. Therefore, larger cities host relatively fewer firms of this industry while product prices are higher compared to smaller cities. However, in Section 3.4, I show that the last case seems to be relevant for over-regulated cities only. The following proposition summarizes my findings.

Proposition 1. *Assume preferences with pro-competitive effects, i.e. $\eta > 0$. Then, there exist $0 < \underline{\alpha} < \overline{\alpha} < 1$ such that a larger city is characterized by: (i) more firms and lower prices in labor-intensive industries, $\alpha > \overline{\alpha}$; (ii) more firms and higher prices in sectors with intermediate intensity of factors, $\underline{\alpha} < \alpha < \overline{\alpha}$; and (iii) fewer firms and higher prices in land-intensive industries, $\alpha < \underline{\alpha}$.*

Proof. In the text.

Proposition 1 states that the market outcome depends on both demand and supply side properties. The economic intuition for this result is straightforward. Firms in land-intensive industries are more sensitive to land prices which are higher in larger cities. Hence, these firms have to set higher product prices in larger cities to compensate for higher production costs. This result is a consequence of the firms' cost minimization problem driven by the land market.

To illustrate the opposite nature of production cost and pro-competitive effects, first, I exclude the former by setting $\alpha = 1$, thus (17) implies prices decrease with city size under the presence of pro-competitive effects. Second, when the pro-competitive effects are absent, we fall back to CES preferences with $\eta = 0$. In this case, the elasticity (17) of the commodity price boils down to $\text{dln}p/\text{dln}L = (1 - \delta)(1 - \alpha) > 0$. Hence, firms always set higher prices in larger cities. Here, only the production cost effect is at work because prices are not affected by market size.

3.2 Land-use regulations

My set-up allows studying the impacts of land-use regulations on product markets. Softening land-use regulations, which corresponds to a higher δ, means easier conversion of land, for example, switching from housing to commercial usage. This makes the CBD size more elastic to city population which results in a larger land supply in the CBD pushing the relative land price (8) down. Therefore, it is readily verified from (11) and (15) that prices decrease while product diversity expands with softer land-use regulations, i.e. higher δ. Furthermore, this effect is stronger for lower α, i.e. for a land-intensive industries.

This result has a direct welfare implication. Softer regulation produces additional entry of firms while individual per-variety consumption x is not altered by changes in δ as implied by (13). Therefore, the indirect utility, $U = Nu(x)$, unambiguously increases. This result is not surprising. As pointed out by a number of empirical studies for UK (Cheshire and Hilber, 2008; Cheshire *et al.*, 2014) and US cities (Turner *et al.*, 2014; Hsieh and Moretti, 2015), land-use regulations have negative welfare consequences. Note that stringent regulations typically target the heritage preservation issue. In this discussion, I am not taking into account the city's level of amenities, which typically decreases with softening regulations and negatively affects welfare with city population growth through a crowding effect. This could outweigh the positive consequences of softer land-use regulations and deliver a similar result as, for example, in Seegert (2011) who shows that an intermediate level of land-use regulation is socially optimal. Note that this result is independent from the implication of regulations of the housing market or of land for commercial usage. Also, investments in heritage preservation directly affect housing price (Koster and Rouwendal, 2017) which I neglect in my analysis.

As to the joint impact of city expansion and regulation, (18) and (20) imply that both thresholds $\overline{\alpha}$ and $\underline{\alpha}$ decrease with δ. In other words, under softer regulation, a larger number of sectors provide broader diversity and lower prices with city population growth. Moreover, comparing an increase in population of two cities with different levels of regulations show that a number of land-intensive industries attract more firms which set lower prices in the city with softer regulations, whereas for the city with stricter regulations the outcome would be opposite. This highlights the role of weaker land-use regulations as a source of social welfare improvement. I summarize these results in the following proposition.

Proposition 2. *Weaker land-use regulations in a city: (i) result in lower prices and broader product diversity while welfare increases; and (ii) lead to lower thresholds $\overline{\alpha}$ and $\underline{\alpha}$. Thus, in larger cities, prod-*

uct diversity is broader and product prices are lower for a larger number of industries when land-use regulations are weaker.

Proof. In the text.

This discussion illustrates the negative consequences of land scarcity for businesses (meaning high production costs) within a full-fledged urban model at least for industries with relatively high land input. I contribute to the literature by highlighting a mechanism which may lead to welfare losses through an increase in product prices and a decrease in product diversity within over-regulated cities. The simple and intuitive reason is an increase in production costs in response to city growth with strict land-use regulations.

3.3 Commuting costs

In addition to the interactions between the competition and production cost effects, the mass of firms (15) is affected by commuting costs τ. In equilibrium, commuting costs are proportionate to urban costs τL. In other words, an increase in commuting costs results in higher expenditure on housing as well. It is readily verified from (15), that larger commuting costs τ lead to a reduction in the mass of firms because individual consumption x is not affected by an increase in τ as shown by (13). Consumers have to spend a larger share of their budget on urban costs which makes the product market smaller. This pushes a fraction of firms out of business. Thus, the differences in the mass of entrants among cities could be a consequence of differences in commuting costs.

Consider now a simple example of two cities with equal size and with higher commuting costs in one of them, i.e., $\tau_1 > \tau_2$. Recall that commuting costs have an impact only on the mass of firms (15) but do not affect product prices (11) and firm sizes (14). Therefore, in the city with lower commuting costs, diversity is broader while consumption levels and product prices are the same as in the other city. This has a direct implication on the welfare of residents in the two cities. Indeed, once consumers are endowed with preferences exhibiting love for variety, residents in the city with lower commuting costs are better off.

The variation in the mass of firms (19) under city population growth is also affected by τ.

Equation (20) which implicitly pins down a threshold value $\underline{\alpha}$, shows that larger commuting costs τ lead to a higher $\underline{\alpha}$. Thus, a smaller number of industries display broader diversity with city growth when commuting costs are higher. Moreover, in our example with two cities, the threshold value $\underline{\alpha}$ is higher in the city with higher commuting costs τ, i.e. $\underline{\alpha_1} > \underline{\alpha_2}$. Assume now that these two cities experience the same shock to population size. An increase in the cities' sizes has a different impact on the industry with $\alpha^* \in (\underline{\alpha_1}, \underline{\alpha_2})$ in these cities only because of the differences in urban costs. To be precise, in the city with higher urban costs, diversity shrinks but the opposite holds in the city with lower urban costs, while product prices in both cities increase. However, the increase in prices is higher for the city with higher commuting costs. Thus, the initial difference in welfare between residents of the two cities increases in response to city population growth. Furthermore, an increase in city size may have opposite welfare consequences for the residents of these cities. Consumers in the city with high urban costs are worse off because of an increase in product prices and a drop in product diversity. Residents of the low commuting cost city might be better off due to broader diversity which outweighs the losses associated with an increase in prices.

3.4 Quantitative illustration

In this section I address the question of plausible values of $\underline{\alpha}$ and $\overline{\alpha}$ for the labor shares α in Proposition 1. To evaluate the thresholds quantitatively as a first approximation, I rely on empirically plausible values of urban costs – share of housing and commuting costs in households' spendings –, demand side variables such as the demand elasticity and super-elasticity, and the elasticity of land price δ with respect to city size.

First, empirical evidence shows that the share of expenditure on housing is between 29% and 34% of household income, with an average of 33.4% for France and 32.8% for the US, while the estimates of commuting costs are 13.5% for France and 17.5% for the US (Combes *et al.*, 2018; US BTS, 2013). Hence, those figures suggest that the urban costs τL comprise up to a half of the household income $1 + \frac{S}{L} \cdot \frac{R}{w} + \frac{1}{wL} \cdot \int_0^L z(t)\mathrm{d}t$ in the largest cities. Furthermore, the elasticity of land prices with respect to city size is, on average, $\overline{\delta} = 0.6$ (Combes *et al.*, 2018).

Second, according to different empirical studies, the elasticity of substitution between varieties in consumption usually takes values between 7 and 11 while the super-elasticity of demand lies between 1 and 2 (Bergstrand *et al.*, 2013; Head and Ries, 2001; Head and Mayer, 2004; Dossche *et al.*, 2010; Beck and Lein-Rupprecht, 2016). Here, I rely on the common property of monopolistic competition models that the price elasticity $1/\varepsilon$ coincides with the elasticity of substitution while the super-elasticity of demand is η.[7]

These figures and the fact that the elasticity of utility $\text{dln}u/\text{dln}x < 1$ lead to a decreasing welfare with city size, i.e, $\text{dln}U/\text{dln}L$ given by (21) is negative for any empirically plausible values of parameters and labor share in production α. In other words, in equilibrium, a city of any size locates on the decreasing part of the utility function. This provides justification for comparison of different size cities due to the existence of smaller cites.

Based on these parameter estimates, I compute values for the thresholds of the labor share α in production based on (18) and (20). My preferred set of parameter values yields a threshold $\overline{\alpha}$ of about 0.85, while the value of $\underline{\alpha}$ is approximately 0.75. In other words, product diversity is broader in larger cities for industries with land shares in production below 0.25. Furthermore, firms in industries with land shares in production below 0.15 set lower prices in larger cities. For the goods of industries with land shares between 0.15 and 0.25, prices are higher in larger cities. The reason is that the competition effect stemming from the larger number of competitors is dominated by the production cost effect.

Recall that my analysis is mostly applicable to service industries which dominate the cities' economic activity. As the next step, I compare my quantification results with empirical estimates to figure out which types of services may demonstrate different patterns. Duranton *et al*. (2015) estimate a land share in services of, on average, 13.5%, and a similar result is shown by Karadi and Koren (2012) whose figure is 13%. For service sectors excluding wholesale, retail and "entertainment" (restaurants, cafes, cinemas, etc.), the land share is estimated at about 9% (Brinkman *et al.*, 2015) which is lower than the average. Therefore, the land shares for traditional retail and food service industries must exceed this average and are likely above 15%.

[7]These empirical estimates were conducted for different demand systems. However, the elasticity of substitution coincides with the demand elasticity in a monopolistic competition framework independently of the demand system.

In this case, quantification findings show that those industries demonstrate higher prices while other services like professional services, information, and finance sectors, offer lower prices in larger cities. These figures also suggest that the third pattern, $\alpha < \underline{\alpha}$, when prices are higher and product diversity is lower, is less relevant empirically for cities with average levels of land-use regulations. Indeed, industries of this pattern must have land share above 0.25 which does not seem plausible for most dominant service sectors in cities.

The previous discussion is related to the average level of land-use regulations, i.e. for the case of $\bar{\delta} = 0.6$. Cities with tighter regulations have an elasticity of land with respect to its population below $\bar{\delta}$. I compute threshold values for those cities, gradually decreasing the elasticity δ. For instance, when $\delta = 0.5$, the thresholds values are $\overline{\alpha} = 0.88$ and $\underline{\alpha} = 0.79$. When $\delta = 0.2$, those values fall to $\overline{\alpha} = 0.92$ and $\underline{\alpha} = 0.87$ meaning that industries with land shares of about 0.08 such as professional services (Brinkman *et al.*, 2015) may have higher price levels in larger cities. In the limiting case, when $\delta \to 0$, the threshold values converge to $\overline{\alpha} = 0.94$ and $\underline{\alpha} = 0.90$. In other words, in over-regulated cities only services with very low shares of land, like finance with land share about 0.04, still satisfy the inverse relationship between price levels and city size. Furthermore, sectors with land shares above 0.10 are smaller in large over-regulated cities.

I also investigate how city population affects the industry size measured as firms' total revenue. On one hand, a larger population leads to higher urban costs, τL, and, therefore, lower spendings on products. On the other hand, it results in an increase in the total city income given by $L(1/\alpha + \tau L/2)$. The overall effect on the industry size $M = LNpx$ is given by

$$\frac{\text{dln}M}{\text{dln}L} = 1 - \frac{\tau L}{\frac{2}{\alpha} - \tau L}.$$

Even for the highest values of urban costs $\tau L = 0.5$ of total income, dln$M$/dln$L$ does not exceed 0.67. In other words, industry size increases less than proportionally to city size. This might be viewed as an alternative interpretation of the different behavior of firms in industries with different production structures in response to city size. To be precise, firms from land-intensive industries suffer from an increase in production costs which may have a negative impact on product prices. Moreover, higher urban costs reinforce this effect. Hence, we need to be careful in discussing the causes of price levels and industry sizes in cities with different populations and commuting costs.

4 Agglomeration effects

Generally, agglomeration effects are beneficial for both consumers and producers (Fujita and Thisse, 2013, ch. 4; Picard and Tabuchi, 2013). Consumers benefit from a broader product diversity within cities where industries on average are more agglomerated. Firms experience higher demand for their products when market interactions among firms become more intensive due to input-output (IO) linkages and produce at lower costs because of knowledge spillovers. Hence, firms benefit from the exploitation of the increasing returns technology. This could result in tougher competition in the presence of pro-competitive effects and, therefore, lower product prices. Thus, reciprocal causality leads to benefits for both producers and consumers.

In this section, I show the positive consequences of agglomeration effects through decreasing product prices and increasing diversity in a city and discuss the impact of intermediate sector size and the strength of knowledge spillovers on the market outcome.

4.1 Input-output linkages

I still consider non-CES preferences given by (1) and extend technology (4) to the case with intermediates. I assume a technology à la Krugman and Venables (1995) where the whole range of varieties is used both in final consumption and production of the differentiated good. To be precise, I rely on the total cost function given by

$$C(q) = (f + cq)w^{\alpha\beta}r^{(1-\alpha)\beta}P^{1-\beta}, \tag{22}$$

where $1 - \beta \in (0,\, 1)$ is the share of intermediates in production and P is the CES price index for intermediate goods,

$$P = \left(\int_0^N p_k^{1-\sigma}\mathrm{d}k\right)^{\frac{1}{1-\sigma}},$$

with the elasticity of technological substitution $\sigma > 1$ across intermediate varieties. I assume a single market for the final and intermediate goods, therefore, both types of buyers, consumers and firms, pay the same equilibrium price for each variety. The demand D_i for variety i is given by

$$D_i(p_i) = D_i^F + D_i^I, \tag{23}$$

where $D_i^F = L(u')^{-1}(\lambda p_i)$ is the demand for final consumption obtained from (3), and D_i^I is the demand for variety i as the intermediate good. The firms' total spending on intermediates is given by $(1-\beta)C(q)$ due to the Cobb-Douglas technology (22), therefore, D_i^I takes the form

$$D_i^I = (1-\beta)(f+cq)N \cdot \frac{p_i^{-\sigma}}{P^{\beta-\sigma}} \cdot w^{\alpha\beta} r^{(1-\alpha)\beta}. \tag{24}$$

At the symmetric equilibrium, the price elasticity $\text{dln}D/\text{dln}p$ of demand for each variety is

$$\frac{\text{dln}D}{\text{dln}p} = \frac{\frac{D^F}{\varepsilon} + \sigma D^I}{D^F + D^I}. \tag{25}$$

Furthermore, using the zero-profit condition $pq = C(q)$ and the firm's budget constraint $(1-\beta)C(q) = p \cdot D^I$, I obtain that in equilibrium the shares of total output used for final and intermediate consumption are constant and equal, respectively, to β and $1-\beta$. The markup m is inverse to (25), thus

$$m = \frac{1}{\frac{\beta}{\varepsilon} + \sigma(1-\beta)}. \tag{26}$$

Equation (26) shows that the equilibrium markup is still a function of individual consumption x only. This representation holds despite the complexity of the supply side due to substitutability of factors and IO linkages, and the complexity of the demand side due to variable markups and the endogenous weights of consumption groups in the elasticity (25). Therefore, preferences with $\eta > 0$ still generate pro-competitive effects, i.e. additional entry leads to a drop in markups.

The factor-market clearing conditions yield

$$L = N \cdot \frac{\partial C(q)}{\partial w} = \alpha\beta N(f + cq) w^{\alpha\beta - 1} r^{(1-\alpha)\beta} P^{1-\beta},$$

$$S = N \cdot \frac{\partial C(q)}{\partial r} = (1-\alpha)\beta N(f + cq) w^{\alpha\beta} r^{(1-\alpha)\beta - 1} P^{1-\beta}.$$

Therefore, the relative land price is still given by

$$\frac{r}{w} = \frac{1-\alpha}{\alpha} \cdot \frac{L}{S}. \tag{27}$$

Plugging (27) and the equilibrium price index

$$P = N^{\frac{1}{1-\sigma}} p$$

into the expression for markup $m = (p - cw^{\alpha\beta} r^{(1-\alpha)\beta} P^{1-\beta})/p$, after normalization $w = 1$, I get the equilibrium relative price

$$p = \left[\frac{c}{(1-m)}\right]^{\frac{1}{\beta}} \cdot N^{-\frac{1-\beta}{\beta(\sigma-1)}} \cdot \left(\frac{1-\alpha}{\alpha} \cdot \frac{L}{S}\right)^{1-\alpha}. \tag{28}$$

Plugging (28) into the zero profit condition $pq = C(q)$, I obtain

$$\frac{qm}{1-m} = \frac{f}{c}.$$

Using $Lx = \beta q$, I get

$$\frac{xm}{1-m} = \beta \cdot \frac{f}{cL}. \tag{29}$$

Finally, (27) implies that the budget constraint (2) may be restated as

$$Npx = \frac{1}{\alpha} - \frac{\tau L}{2}. \tag{30}$$

Before discussing the impact of agglomeration economies on the market outcome, I show that, with a sufficiently large intermediate good sector, some standard properties do not hold.

Indeed, using the duality principle, (22) may be represented with a production function given by

$$q = \frac{1}{c} \cdot \left(\frac{1}{N} \cdot \frac{L^{\alpha\beta} S^{(1-\alpha)\beta} H^{1-\beta}}{C} - f \right), \tag{31}$$

where $H = \left(\int_0^N h_k^{\frac{\sigma-1}{\sigma}} \mathrm{d}k \right)^{\frac{\sigma}{\sigma-1}}$ is the CES aggregator over varieties, h_k is the output for intermediate consumption, while $C > 0$ is a constant. In a symmetric outcome $H = hN^{\frac{\sigma}{\sigma-1}}$, which leads to the following form of the production function

$$q = \frac{1}{c} \cdot \left(\frac{L^{\alpha\beta} S^{(1-\alpha)\beta} h^{1-\beta}}{CN^{\frac{\beta\sigma-1}{\sigma-1}}} - f \right).$$

Hence, when the intermediate good sector is large, i.e. $\beta < 1/\sigma$, each firm's output q increases with entry. In other words, the business stealing effect, which is typically present when varieties and their markets are interdependent, is missing. In what follows, I focus on the case where the intermediate sector size is bounded, i.e. $\beta > 1/\sigma$, and study how IO linkages shape the market outcome under city population growth.

To this end, I provide an analysis of the impact of city size on the market outcome in Appendix B. For the sake of distinguishing between the different effects at work, I shut down the impact of land-use regulation by setting $\delta = 0$. I show in Appendix B that the thresholds $\overline{\alpha} = \overline{\alpha}(\beta)$ and $\underline{\alpha} = \underline{\alpha}(\beta)$ now depend on the size of the intermediate good sector, $1 - \beta$, and are the solutions to the following equations, respectively:

$$\alpha - \frac{1-\beta}{\beta(\sigma-1)} \cdot \frac{\tau L}{\frac{2}{\alpha} - \tau L} = \frac{(\beta - m)\eta m}{(1-m)\varepsilon + \beta\eta m} + \frac{\beta\sigma - 1}{\beta(\sigma-1)} \cdot \frac{(1-m)\varepsilon}{(1-m)\varepsilon + \beta\eta m}, \tag{32}$$

$$\alpha - \frac{\tau L}{\frac{2}{\alpha} - \tau L} = \frac{(\beta - m)\eta m}{(1-m)\varepsilon + \beta m\eta}. \tag{33}$$

What do IO linkages bring to the analysis? First, it is readily verified that the right-hand sides of (32) and (33) increase with β. Hence, a larger intermediate good sector (lower β) leads to a decrease in both threshold values $\overline{\alpha}(\beta)$ and $\underline{\alpha}(\beta)$. In addition, one can show that both functions on the right-hand sides of (32) and (33) are concave and $\overline{\alpha}(\beta) > \underline{\alpha}(\beta)$ when urban costs τL are

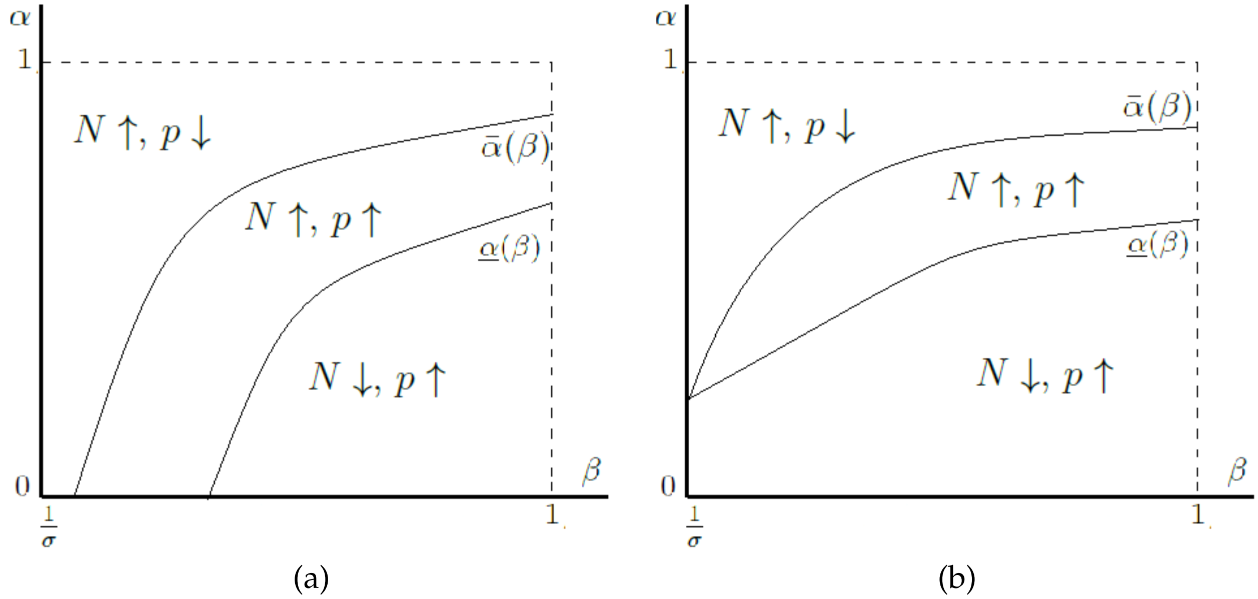

Figure 1: The pattern of market outcome: (a) $\sigma > 1/\varepsilon$; (b) $\sigma < 1/\varepsilon$.

not too large. Moreover, whether the elasticity of substitution for final consumption is larger (smaller) than in production, i.e. $\sigma > 1/\varepsilon$ ($\sigma < 1/\varepsilon$), two slightly different patterns of the market outcome arise. To be precise, the pattern for $\sigma > 1/\varepsilon$ is presented on the left-hand panel of Figure 1, otherwise the market patterns rely on the right-hand panel.

I summarize my findings in the following Proposition.

Proposition 3. *Stronger IO linkages (i) increase the number of industries featuring lower prices in larger cities, and (ii) lead to broader product diversity for the larger number of industries in bigger cities.*

Proof. In the text.

To discuss the impact of IO linkages, consider two industries where the first industry has stronger IO linkages, i.e. $\beta_1 < \beta_2$. Therefore, other things equal, a larger city is likely to host more firms from the first industry while prices for the first industry's good tend to be lower in a larger city. This result stems directly from the fact that the intervals for positive effects are higher for the first industry, i.e. $\overline{\alpha}_1(\beta) < \overline{\alpha}_2(\beta)$ and $\underline{\alpha_1}(\beta) < \underline{\alpha_2}(\beta)$.

In the same vein, city population growth is more likely to result in a drop in product prices and an increase in product diversity for industries that exploit IO linkages more intensively. Hence, agglomeration economies also improve welfare in addition to the automatization process. Proposition 3 shows that stronger IO linkages allow industries to compete more effectively in larger cities with high land prices within the CBD.

IO linkages also build an additional connection between urban costs and firms' pricing. Indeed, when IO linkages are negligible, urban costs do not affect prices and the threshold value $\overline{\alpha}$ given by (18). However, (32) implies that this is not the case when $\beta < 1$. Commuting costs matter for both product prices and the mass of firms. Let me come back to my example with two cities of the same size but with different commuting costs. It is readily verified from (32)-(33) that both thresholds $\overline{\alpha}(\beta)$ and $\underline{\alpha}(\beta)$ are higher for the city with high commuting costs. Hence, for the industry with stronger IO linkages, prices are lower and diversity is broader in the city with low commuting costs.

In addition, population growth in each of these two cities may have different consequences for the industry. In particular, an increase in city size is more likely to result in higher product prices and lower diversity in the city with higher commuting costs. The reason is that high commuting costs have a negative impact on the industry which is reinforced by city size. In other words, consumers have to spend more on housing and transportation with city growth, hence, the increase in product diversity is smaller in the city with higher commuting costs.

4.2 Knowledge spillovers

Finally, I investigate how knowledge spillovers shape the market prices and product diversity. To this end, I modify the production cost function (4) in the following way:

$$C(q) = N^{-\gamma}(f + cq)w^{\alpha}r^{1-\alpha}, \tag{34}$$

where the new term $N^{-\gamma}$ stands for the knowledge spillovers and $\gamma \in (0, 1)$ measures their strength.

One can show that the relative factor price and zero-profit condition are still given by (8) and (13), respectively. However, the equilibrium product price takes the form

$$\frac{p}{w} = \frac{cN^{-\gamma}}{1-\varepsilon} \cdot \left(\frac{r}{w}\right)^{1-\alpha}. \tag{35}$$

Plugging (34)-(35) into the budget constraint (2), I obtain

$$N^{1-\gamma} \cdot \frac{cx}{1-\varepsilon} \cdot \left(\frac{1-\alpha}{\alpha} \cdot \frac{L}{S}\right)^{1-\alpha} = \frac{1}{\alpha} - \frac{\tau L}{2}. \tag{36}$$

Making use of (16), the elasticity of (36) with respect to L takes the form

$$\frac{\mathrm{dln}N}{\mathrm{dln}L} = \frac{1}{1-\gamma} \cdot \left[\alpha - \frac{\tau L}{\frac{2}{\alpha} - \tau L} - \frac{\eta \cdot (1-\varepsilon)}{1-\varepsilon+\eta}\right]. \tag{37}$$

Thus, the threshold value $\underline{\alpha}$ is still given by (20). Therefore, knowledge spillovers magnify the effect of city population size discussed in Section 3.1 while the threshold value $\underline{\alpha}$ is not affected due to Hicks neutrality. To be precise, for industries with high input shares of labor, $\alpha > \underline{\alpha}$, stronger knowledge spillovers make elasticity (37) larger while the opposite holds for land-intensive industries with $\alpha < \underline{\alpha}$.

Taking the elasticity of price (35), I get

$$\frac{\mathrm{dln}p}{\mathrm{dln}L} = 1 - \alpha - \frac{\varepsilon\eta}{1-\varepsilon+\eta} - \gamma \cdot \frac{\mathrm{dln}N}{\mathrm{dln}L}. \tag{38}$$

Comparison between (17) and (38) shows, that the last term in (38) stands for the impact of knowledge spillovers on price behavior. For land-intensive industries with $\alpha < \underline{\alpha}$, $\mathrm{dln}N/\mathrm{dln}L < 0$, therefore, knowledge spillovers lead to a stronger increase in their product prices with population size growth. However, for industries with $\alpha > \underline{\alpha}$, $\mathrm{dln}N/\mathrm{dln}L > 0$ which (i) makes the elasticity of the product price (38) higher, and (ii) increases the threshold value $\overline{\alpha}$ for different patterns of pricing. The intuition is as follows. An increase in city population raises the mass of firms for industries with $\alpha > \underline{\alpha}$ at a greater rate than in the absence of knowledge spillovers. This makes the competition effect stronger which, in turn, leads to a greater drop in product prices for labor-intensive industries, $\alpha > \overline{\alpha}$, and suppresses a price increase for industries with intermediate values of labor share input, $\underline{\alpha} < \alpha < \overline{\alpha}$ (see bullet (ii) of Proposition 1). Furthermore, for the upper-tail of these industries, the effect is strong enough to revert the pricing pattern. Thus, under the presence of knowledge spillovers, an increase in city population leads to lower prices for a larger number of industries with intermediate values of labor share input than in the case without knowledge spillovers. For land-intensive industries, $\alpha < \underline{\alpha}$, the effects work in opposite direction.

Last, an increase in the strength of knowledge spillovers, i.e. a larger γ, results in a larger number of industries featuring lower prices in larger cities. Furthermore, an increase in γ produces a scale effect on diversity. For industries with $\alpha > \underline{\alpha}$, an increase in city population leads to a greater increase in diversity while the effect is opposite for land-intensive industries. I summarize my findings in the following Proposition.

Proposition 4. *Stronger knowledge spillovers (i) increase the number of industries featuring lower prices in larger cities; (ii) reinforce the effect of broader diversity for labor-intensive industries and industries with intermediate labor input ($\alpha > \underline{\alpha}$) in larger cities, while the effect is opposite for land-intensive industries ($\alpha < \underline{\alpha}$).*

Proof. In the text.

5 Conclusion

In this paper, I shed additional light on the role of land prices and land-use regulations for product prices and diversity within large cities. I provide a comprehensive analysis based on a micro-founded model that shows why and how industries with different cost structures may demonstrate different patterns of price in cities of different sizes. In particular, I show that firms from land-intensive sectors set higher prices in larger cities with high CBD land prices. In other words, high prices for the products of these industries could be a consequence of the variation in land prices and urban costs in cities. Moreover, I contribute to the literature by showing how tighter land-use regulations could affect the market outcome of industries and, therefore, the well-being of citizens.

I also show that a higher concentration of service industries in large cities is linked to a lower share of land which could be the result of successfully adopting technology such as intensive use of computers, which replace traditional technologies requiring higher relative inputs of land. A number of industries experienced such shocks leading to drastic decreases in their relative shares of land in the production process. I believe that the estimation of production costs and, in particular, the share of land input, in various industries within and across cities could highlight additional factors that shape product prices and diversity in cities.

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Appendices

Appendix A

Taking the elasticities of (13) with respect to L, I obtain:

$$\frac{(x\varepsilon' + \varepsilon)(1-\varepsilon) + x\varepsilon'\varepsilon}{(1-\varepsilon)^2} \cdot \frac{1-\varepsilon}{x\varepsilon} \cdot x \cdot \frac{\text{dln}x}{\text{dln}L} = -1,$$

or, after simplifications, I get (16):

$$\frac{\text{dln}x}{\text{dln}L} = -\frac{1-\varepsilon}{1-\varepsilon+\eta}.$$

Plugging (8) into (11), I get

$$\frac{p}{w} = \frac{c}{1-\varepsilon} \cdot \left(\frac{1-\alpha}{\alpha} \cdot \frac{L}{S}\right)^{1-\alpha}.$$

Then, the elasticity of price with respect to L takes the form

$$\frac{\text{dln}p}{\text{dln}L} = \frac{(1-\varepsilon)x\varepsilon'}{(1-\varepsilon)^2} \cdot \frac{\text{dln}x}{\text{dln}L} + 1 - \alpha.$$

Plugging (16) into last equation, I get

$$\frac{\text{dln}p}{\text{dln}L} = 1 - \alpha - \frac{x\varepsilon'}{1-\varepsilon} \cdot \frac{1-\varepsilon}{1-\varepsilon+\eta} =$$

$$= 1 - \alpha - \frac{\varepsilon\eta}{1-\varepsilon+\eta}.$$

Using (15), I obtain

$$\frac{\mathrm{dln}N}{\mathrm{dln}L} + \frac{\mathrm{d}}{\mathrm{dln}L}\ln\left(\frac{cx}{1-\varepsilon}\right) + 1 - \alpha = -\frac{\frac{\tau L}{2}}{\frac{1}{\alpha} - \frac{\tau L}{2}},$$

or,

$$\frac{\mathrm{dln}N}{\mathrm{dln}L} + \frac{1-\varepsilon+x\varepsilon'}{(1-\varepsilon)^2} \cdot \frac{1-\varepsilon}{x} \cdot x \cdot \frac{\mathrm{dln}x}{\mathrm{dln}L} + 1 - \alpha = -\frac{\frac{\tau L}{2}}{\frac{1}{\alpha} - \frac{\tau L}{2}}.$$

Making use of (16)

$$\frac{\mathrm{dln}N}{\mathrm{dln}L} - \frac{1-\varepsilon+x\varepsilon'}{(1-\varepsilon)^2} \cdot (1-\varepsilon) \cdot \frac{1-\varepsilon}{1-\varepsilon+\eta} + 1 - \alpha = -\frac{\tau L}{\frac{2}{\alpha} - \tau L},$$

I finally obtain (19):

$$\frac{\mathrm{dln}N}{\mathrm{dln}L} = \alpha - \frac{\tau L}{\frac{2}{\alpha} - \tau L} - \frac{\eta(1-\varepsilon)}{1-\varepsilon+\eta}.$$

Appendix B

Per capita consumption is pinned down by the zero-profit condition (29) which is very similar to zero-profit condition (13) under the absence of intermediates described in Section 3. Note that (13) may be obtained from (29) as a limiting case when $\beta \to 1$. Moreover, the relative change in per capita consumption x in response to shocks in city population size qualitatively the same to the case without intermediates. To be precise, using (29) and (26) I obtain that the elasticity $\mathrm{dln}x/\mathrm{dln}L$ of per capita consumption is negative and given by

$$\frac{\mathrm{dln}x}{\mathrm{dln}L} = -1 + \frac{\beta m\eta}{(1-m)\varepsilon + \beta m\eta} > -1.$$

Using (26), I obtain the markup behavior

$$\frac{\mathrm{dln}m}{\mathrm{dln}L} = \frac{\beta m\eta}{\varepsilon} \cdot \frac{\mathrm{dln}x}{\mathrm{dln}L}$$

which is similar to the case when $\beta = 1$. Indeed, increasing elasticity of final good demand

$\eta > 0$ leads to pro-competitive effects and markup decreases with market size L.

Using (28) and (30), I derive the elasticities $\mathrm{dln}p/\mathrm{dln}L$ and $\mathrm{dln}N/\mathrm{dln}L$ of the mass of firms and prices with respect to L:

$$\frac{\mathrm{dln}p}{\mathrm{dln}L} + \frac{1-\beta}{\beta(\sigma-1)}\frac{\mathrm{dln}N}{\mathrm{dln}L} = 1 - \alpha - \frac{1}{\beta} \cdot \frac{\mathrm{dln}(1-m)}{\mathrm{dln}L},$$

$$\frac{\mathrm{dln}p}{\mathrm{dln}L} + \frac{\mathrm{dln}N}{\mathrm{dln}L} + \frac{\mathrm{dln}x}{\mathrm{dln}L} = -\frac{\tau L}{\frac{2}{\alpha} - \tau L}.$$

After simplifications, I obtain

$$\frac{\mathrm{dln}p}{\mathrm{dln}L} = \frac{\beta(\sigma-1)}{\beta\sigma-1}\left(\frac{\beta(\sigma-1)(\beta-m)m\eta + (\beta\sigma-1)(1-m)\varepsilon}{\beta(\sigma-1)((1-m)\varepsilon+\beta m\eta)} - \alpha + \frac{1-\beta}{\beta(\sigma-1)} \cdot \frac{\tau L}{\frac{2}{\alpha}-\tau L}\right). \quad (39)$$

and

$$\frac{\mathrm{dln}N}{\mathrm{dln}L} = \frac{\beta(\sigma-1)}{\beta\sigma-1}\left(\alpha - \frac{\beta-m}{(1-m)\varepsilon+\beta m\eta}m\eta - \frac{\tau L}{\frac{2}{\alpha}-\tau L}\right) \quad (40)$$

Note the elasticities (39)-(40) have opposite signs for the cases when $\beta > 1/\sigma$ or $\beta < 1/\sigma$. However, as pointed out in the Section 4.1, I focus on the former case, i.e. $\beta > 1/\sigma$. Hence, the thresholds values of $\overline{\alpha}(\beta)$ and $\underline{\alpha}(\beta)$ are the solutions to (32) and (33), respectively.