Cattle, Steaks and Restaurants: Development Accounting when Space Matters*

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Abstract

We conduct sector-level development accounting in a macro model where land and location play a role. Producers in agriculture, manufacturing and services choose their location to trade off transport costs to the city center and rents. We solve for the spatial equilibrium and show how space affects the aggregate production function and measured productivity. Studies not accounting for sector location will deem services in large, expensive cities unproductive. This biases development accounting because rich countries have large service-cities. Our preliminary calibrations show that, correcting for sector location, service productivity varies as much across countries as manufacturing productivity does. This is in contrast with previous studies that found smaller variation in service productivity.

Productivity is much lower in poor countries than in rich ones (Klenow and Rodriguez-Clare (1997), Hall and Jones (1999), Caselli (2005)). To understand the fundamental causes of productivity differences, it is important to identify the sectors in which these differences are the greatest. Several recent papers have studied the sectoral composition of productivity differences by using data on sector-level inputs, outputs and prices (Baily and Solow (2001), Caselli (2005), Duarte and Restuccia (2010), Restuccia, Yang, and Zhu (2008)). Their main result is that productivity

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differences are sizeable and they are larger in agriculture than in manufacturing and services.[1]

Productivity estimation is always contingent on the set of inputs included in the production function and their quality. Unobserved variation in the quantity or quality of inputs will necessarily show up as variation in productivity. Here we argue that land input has been conspicously (?) missing from development accounting exercises to date.

Controlling for land when estimating macro productivity is important for two reasons. First, countries with high population density are relatively scarce in land and, to the extent that land matters in production, these countries will be deemed less productive. Second, land varies in a crucial quality component: its proximity to consumers. Urban land is more valuable because it is more productive in producing XX. Again, countries may differ in the availability of urban land, thus biasing productivity estimates.

Accounting for land and location is especially important for sector-level development accounting. Agriculture uses land intensively and will be especially sensitive to controlling for the quantity of land. Services, in turn, locate in urban areas and will be especially sensitive to controlling for location. XX RELEVANCE

We build a simple multi-sector general equilibrium model. Each sector uses labor (or a composite of other spatially mobile inputs) and land. The location of sectors is determined in the canonical von Thünen city model. In the model, all trade happens in the city center, the central business district (CBD). Producers choose their location freely on a plane, and have to pay a shipping cost to transport their goods to the CBD. This spatial structure introduces variable land-quality to the model, as land closer to the CBD saves on transport cost. Equilibrium rents decrease with distance from the CBD, and the producers optimally choose locations to balance savings on transport costs to higher rents. Our model yields a simple spatial equilibrium in which agriculture ("cattle") locates farthest away from the center, manufacturing ("steaks") occupies a ring outside the center, and services ("restaurants") are in a central circle.

There are two reasons why development accounting in our model is different from models without land. First, as some sectors are more land intensive, their prices may be more sensitive to rents. Because of this, conditional on productivity, agricultural prices will be relatively higher in rich countries. Second, because sectors endogenously choose locations, their price is also affected by the rent gradient: the speed with which

[1] These results are in line with the classic Balassa-Samuelson literature (Balassa (1964), Samuelson (1964), Baumol and Bowen (1965), Baumol (1967)), which explains sectoral price-level differences by productivity advantage of manufacturing over services.

rents decline in distance from the city center. Urban sectors will be relatively more expensive in countries where the rent gradient is higher (larger, more service-intensive, more urbanized countries).

To quantify the importance of these two mechanisms, we calibrate our model in a set of developed and emerging-market countries with comparable data on sector level productivites and prices.[2] We set common technology parameters to match the sectoral land-shares and spatial distribution of economic activities in the U.S., and allow international variation in the level of urbanization and sector-shares of output. We then use the calibrated model to infer location-corrected sector-level productivities for each country. Our main question is whether explicitly controlling for endogenous location choice has the potential to change previous quantitative conclusions on sectoral productivity differences.

XX RESULTS

Beyond the development accounting papers cited above, our work is related to MACRO URBAN

1 Motivating facts

1. The rent gradient increases with development. Urban land becomes more important both in absolute terms and relatively. (Clark, 2007) 2. The relative price of services increase with development. Baumol's cost disease. 3. Rich countries are more urbanized. 4. Rich countries produce less agriculture and more services.

2 A model of industry location

We introduce location choice to a multi-sector general equilibrium model. We have three sectors: agriculture, manufacturing and services, each using land and labor for production. Our spatial structure follows the von Thünen monocentric city model: producers choose a location on the plane and need to transport their goods to the central business district.

[2] We are using the EUKLEMS database, see O'Mahony and Timmer (2009).

2.1 Consumers

Consumers have Cobb–Douglas preferences across goods produced by the three sectors,

$$U = C_1^{\alpha_1} C_2^{\alpha_2} C_3^{\alpha_3}, \tag{1}$$

with $\sum_{i=1}^{3} \alpha_i = 1$. They supply labor N inelastically, and rent land to producers in a competitive market. They are *absentee landlords*: the rents they collect are independent of the place of employment.

Their budget constraint is

$$PC = WN + \int_z R(z)\tilde{L}(z)dz, \tag{2}$$

where $C = \Pi_{i=1}^{3} C_i^{\alpha_i}$ and $P = \Pi_{i=1}^{3} P_i^{\alpha_i} / \Pi_{i=1}^{3} \alpha_i^{\alpha_i}$ are the quantity and price of the composite good, respectively. $R(z)$ is the rent as a function of the distance to the center (see later), and W is the wage. Because labor is freely mobile, wages do not depend on location.

The parameters α_i determine the sectoral consumption shares:

$$\alpha_i = \frac{P_i C_i}{PC}.$$

2.2 Producers

2.2.1 Technology

Output in sector i at location z depends on employment N and land L used at that location,

$$Q_i(z) = A_i L_i(z)^{\beta_i} N_i(z)^{1-\beta_i}.$$

We take labor to be freely mobile within the country, land is in fixed $\tilde{L}(z)$ supply in each location. The names "land" and "labor" are for the sake of convenience, these two factors correspond to spatially fixed and mobile factors, respectively, and we will calibrate them accordingly.

Sectors differ in their land shares β_i and Hicks neutral productivity shifter A_i.

All products are sold and consumed at a single location, the central business district. This is location $z = 0$, so that z indexes distance to the center.

2.2.2 Shipping

To ship a product to the center, one has to incur shipping costs. If a unit of product i leaves location z, only

$$e^{-\tau_i z}$$

units arrive at the center. This is akin to the iceberg assumption of transport costs. Sectors also differ in the intensity of shipping costs τ_i.

2.2.3 Profits

Profits in sector i from production at z is

$$\Pi_i(z) = P_i e^{-\tau_i z} Q_i(z) - W N_i(z) - R(z) L_i(z). \tag{3}$$

A sector being active at location z requires that their maximized profit $\max \Pi_i(z) \geq 0$.

2.3 Single-city Equilibrium

We begin by characterizing the equilibrium of a single city with fixed amount of land and labor.

The competitive spatial equilibrium in a circular city $z \in Z$ is an equilibrium set of quantities $\{C_i, Q_i(z), L_i(z), N_i(z)\}_{i=1}^3$ and prices $\{P_i, R(z), W\}_{i=1}^3$ such that

1. The consumer chooses $\{C_i\}_{i=1}^3$ to maximize utility (1) subject to its budget constraint (2), taking prices as given.

2. The producers choose technology i and location z, and nonnegative quantities $\{Q_i(z), L_i(z), N_i(z)\}$ to maximize their profits (3), taking prices as given.

3. Sectoral goods market clear: $C_i = \int_{z \in Z} e^{-\tau_i z} Q_i(z) dz$ for $i = 1, 2, 3$.

4. Labor market clears: $N = \sum_i \int_{z \in Z} N_i(z)$.

5. Land markets clear at every location: $\sum_i L_i(z) = \tilde{L}(z)$ for all $z \in Z$.

2.4 Spatial structure

The equilibrium, as we show below, has a simple and intuitive structure. Sectors with higher transport cost intensity (τ_i) and lower land share (β_i) locate closer to the center. Realistically, services locate in a circle around the center, manufacturing goods are produced on a ring around it, and agriculture inhibits the outer ring.

To see why it is the case, it is instructive to construct the sectoral bid rent curves $R_i(z)$. These are the maximum rent an active producer with technology i would be willing to pay at location z. A profit maximizing producer is choosing its land $N_i(z)$ and labor demand $L_i(z)$ to equalize the value marginal product of land and labor to rents and wages, respectively. It is true for any rent function or wages it might face, so it is true for rents given by its own bid-rent curve $R_i(z)$, in particular.

$$R_i(z) = \beta_i P_i e^{-\tau_i z} A_i \left(\frac{N_i(z)}{L_i(z)}\right)^{1-\beta_i} \tag{4}$$

$$W = (1-\beta_i) P_i e^{-\tau_i z} A_i \left(\frac{N_i(z)}{L_i(z)}\right)^{-\beta_i} \tag{5}$$

The sectoral labor-land ratio (employment density) can be expressed as

$$\frac{N_i(z)}{L_i(z)} = \frac{1-\beta_i}{\beta_i} \frac{R_i(z)}{W}. \tag{6}$$

Substituting this into the FOC for land, we can get an implicit expression for the sectoral bid rent curve:

$$R_i(z) = \beta_i P_i e^{-\tau_i z} A_i \left(\frac{1-\beta_i}{\beta_i} \frac{R_i(z)}{W}\right)^{1-\beta_i},$$

from which

$$R_i(z) = \beta_i (1-\beta_i)^{1/\beta_i - 1} (P_i A_i)^{1/\beta_i} W^{1-1/\beta_i} e^{-\frac{\tau_i}{\beta_i} z}. \tag{7}$$

Equation (7) pins down the gradient of the sectoral rent curve, which determines how fast the bid-rents decrease with the distance from the CBD. The gradient is an increasing function of the sectoral transport costs and a decreasing function of land shares $|\partial \log R_i(z)/\partial \log z| = \tau_i/\beta_i$. Intuitively, transport costs ($\tau_i z$) increase with distance, so producers offer lower rents for farther locations. If land were the only factor of production ($\beta_i = 1$), only this direct effect would be present and the gradient would only depend on the transport cost intensity. With labor present, however, the producers can substitute labor for land, introducing an indirect effect on the gradient. As the equilibrium land-labor ratio shows (see equation 6), the land share β_i determines the strength of this substitutability: higher land share implies bid-rent curves decreasing with a slower rate.

We can also get the employment gradient by substituting the bid rent curve into the labor-land ratio,

$$\frac{N_i(z)}{L_i(z)} = (1-\beta_i)^{1/\beta_i} \left(\frac{P_i A_i}{W}\right)^{1/\beta_i} e^{-\frac{\tau_i}{\beta_i} z}. \tag{8}$$

This is the relationship we use to calibrate the sectoral transport cost intensities.

Proposition 1. *Assume that $\tau_s/\beta_s > \tau_m/\beta_m > \tau_a/\beta_a > 0$.*[3] *There exists a unique competitive spatial equilibrium. The structure of this equilibrium is a simple partitioning, with locations $0 < z_1, z_2 < z_3$ such that services with the higher τ_i/β_i rate*

[3]It is straightforward to see that in the knife-edge case of equality, the equilibrium were not unique and not necessarily a simple partitioning.

locate closest to the CBD in $[0, z_1]$*, manufacturing locates in* $(z_1, z_2]$*, and agriculture locates in* $(z_2, z_3]$.

Proof. Sketch of proof:

Existence and uniqueness: The proof shows that there is exactly one vector of prices (P_1, P_2, P_3), such that $R_i(z) \geq R_{-i}(z)$ for $z \in [z_{i-1}, z_i]$ for $i = 1, 2, 3$. with goods and labor markets clearing. [TO BE COMPLETED]

Structure: To see why the spatial competitive equilibrium generates a simple partition, it is instructive to look at figure 2.4. The graphical proof is based on the shape of the sectoral bid rent curves. Under our assumptions, sectoral bid-rent curves are strictly decreasing with location (z). Let's normalize $W = 1$. The equilibrium prices P_i influence the position of the bid-rent curves, with higher prices implying higher bid-rents for each location. In equilibrium, a sector i is active in location z if $R_i(z) \geq R_{-i}(z)$, where $-i$ denotes the other sectors. We are to show that in equilibrium there are a vector of locations (z_1, z_2) (z_3, the urban fringe is exogenously given), such that $0 \leq z_i \leq z_3$ and $R_i(z) \geq R_{-i}(z)$ for $z \in [z_{i-1}, z_i]$ for $i = 1, 2, 3$.

The equilibrium requires that $R_1(z)$ crosses once with $R_2(z)$ at $z = z_1$. Similarly, $R_2(z)$ crosses once with $R_3(z)$ at $z = z_2$. The strictly decreasing bid-rent curves imply that they cross *at most* once. If equilibrium prices were such that one of them did not cross with any other at all, that sector would not produce. As our Cobb-Douglas utility function implies positive demand for each good, this would contradict the equilibrium. $z_1 < z_2$, otherwise sector 1 would not produce. $z_2 < z_3$, otherwise sector 3 would not produce. $\square$

2.5 Spatial arbitrage

Competitive land markets ensure that each location goes to the highest bidder. The slope of the bid-rent gradient in sector i is τ_i/β_i. Suppose that this is the highest for services, lower for manufacturing, and lowest for agriculture.

Let z_i denote the outer edge of the land use of sector i. At such locations, both sector i and sector $i + 1$ have the same reservation rent:

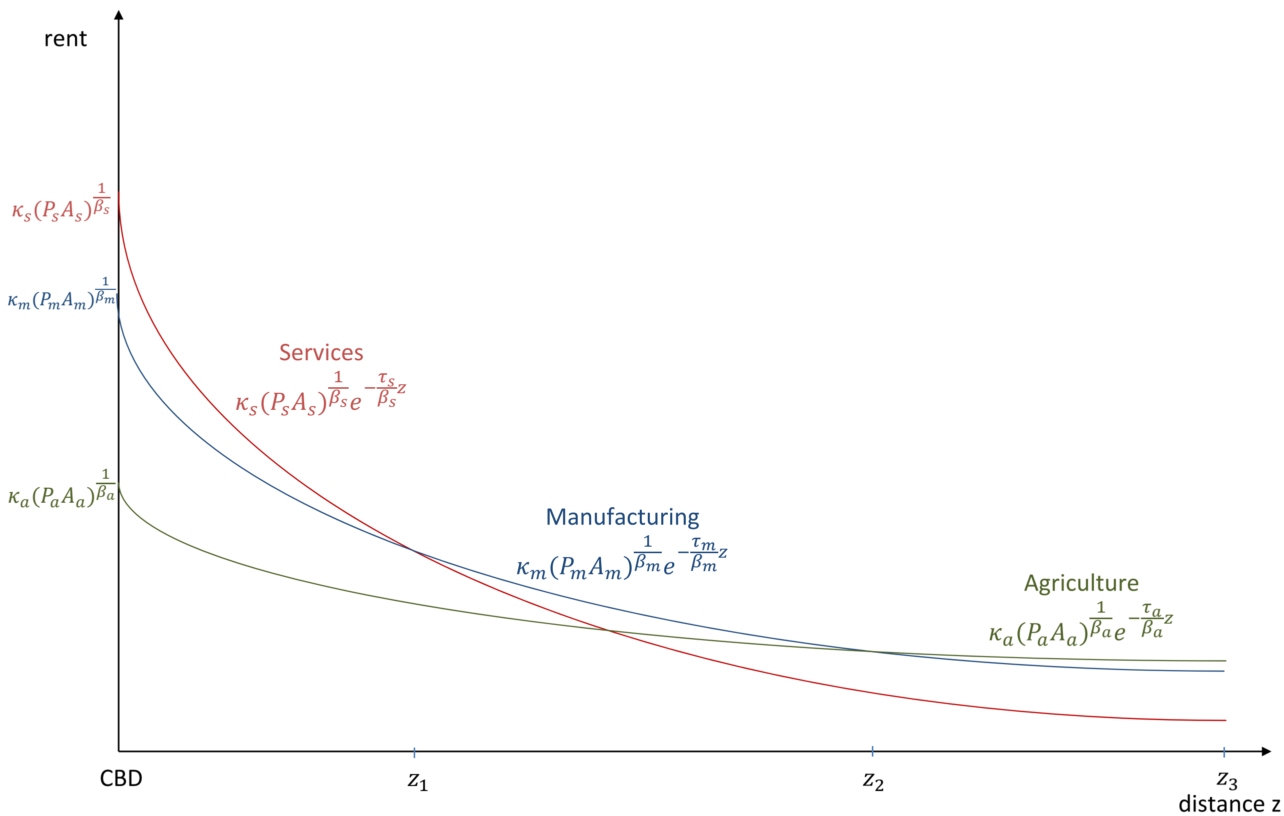
$$R(z_i) = \beta_i(1 - \beta_i)^{1/\beta_i - 1}(P_i A_i)^{1/\beta_i} W^{1-1/\beta_i} e^{-\frac{\tau_i}{\beta_i} z_i} \tag{9}$$

$$R(z_i) = \beta_{i+1}(1 - \beta_{i+1})^{1/\beta_{i+1} - 1}(P_{i+1} A_{i+1})^{1/\beta_{i+1}} W^{1-1/\beta_{i+1}} e^{-\frac{\tau_{i+1}}{\beta_{i+1}} z_i} \tag{10}$$

Substitute in the overall amount of value added, $Y_i = P_i Q_i$,

$$R_i(z) = R_i e^{-\frac{\tau_i}{\beta_i}(z - \tilde{z}_i)}.$$

Figure 1: Spatial equilibrium



The figure plots the structure of a spatial competitive equilibrium. It shows equilibrium sectoral bid rent curves as a function of distance from the city center. A sector is active over an area where it is willing to overbid alternative sectors. Crossings of the bid-rent curves determine the borders of the sectors. Services are active in $[0, z_1]$, manufacturing in $(z_1, z_2]$, and services in $(z_2, z_3]$.

$$R_i = \frac{\beta_i Y_i}{L_i}$$

$$R_i(z) = \frac{\beta_i Y_i}{L_i} e^{-\frac{\tau_i}{\beta_i}(z-\tilde{z}_i)}.$$

At the location z_{i-1} where sectors i and $i-1$ meet,

$$\frac{\beta_{i-1} Y_{i-1}}{L_{i-1}} e^{-\frac{\tau_{i-1}}{\beta_{i-1}}(z_{i-1}-\tilde{z}_{i-1})} = \frac{\beta_i Y_i}{L_i} e^{-\frac{\tau_i}{\beta_i}(z_{i-1}-\tilde{z}_i)}.$$

To solve for the barriers, we use the fact that $Y_{i-1}/Y_i = \alpha_{i-1}/\alpha_i$,

$$\frac{\alpha_{i-1}\beta_{i-1}}{\alpha_i\beta_i} = \frac{\int_{z\in Z_{i-1}} \tilde{L}(z)dz}{\int_{z\in Z_i} \tilde{L}(z)dz} e^{\frac{\tau_{i-1}}{\beta_{i-1}}(z_{i-1}-\tilde{z}_{i-1})-\frac{\tau_i}{\beta_i}(z_{i-1}-\tilde{z}_i)}.$$

2.6 Solving for the prices

At the sector borders z_i, neighboring sectors have the same reservation rents. Having solved for these locations, equations 9 provide implicit equations for relative product prices P_i for $i = s, m$. The consumer budget constraint, given by equation 2, gives us the equation for the remaining product price P_a. This closes the model description.

2.7 Linear city

A linear city is one with $\tilde{L}(z) = l$ everywhere.

$$\tilde{z}_i = z_{i-1} - \frac{\beta_i}{\tau_i} \ln \frac{1 - e^{-\frac{\tau_i}{\beta_i}(z_i - z_{i-1})}}{\tau_i/\beta_i}.$$

$$e^{\frac{\tau_i}{\beta_i}(\tilde{z}_i - z_{i-1})} = \frac{\tau_i/\beta_i}{1 - e^{-\frac{\tau_i}{\beta_i}(z_i - z_{i-1})}}$$

$$e^{\frac{\tau_{i-1}}{\beta_{i-1}}(z_{i-1}-\tilde{z}_{i-1})} = e^{\frac{\tau_{i-1}}{\beta_{i-1}}(z_{i-1}-z_{i-2}+z_{i-2}-\tilde{z}_{i-1})} = e^{\frac{\tau_{i-1}}{\beta_{i-1}}(z_{i-1}-z_{i-2})} e^{-\frac{\tau_{i-1}}{\beta_{i-1}}(\tilde{z}_{i-1}-z_{i-2})} =$$

$$e^{\frac{\tau_{i-1}}{\beta_{i-1}}(z_{i-1}-z_{i-2})} \frac{1 - e^{-\frac{\tau_{i-1}}{\beta_{i-1}}(z_{i-1}-z_{i-2})}}{\tau_{i-1}/\beta_{i-1}}$$

In this case, spatial arbitrage dictates

$$\frac{\alpha_{i-1}\beta_{i-1}}{\alpha_i\beta_i} = \frac{z_{i-1} - z_{i-2}}{z_i - z_{i-1}} e^{\frac{\tau_{i-1}}{\beta_{i-1}}(z_{i-1}-\tilde{z}_{i-1})-\frac{\tau_i}{\beta_i}(z_{i-1}-\tilde{z}_i)}.$$

which becomes

$$\frac{\alpha_{i-1}\beta_{i-1}}{\alpha_i\beta_i} = e^{\frac{\tau_{i-1}}{\beta_{i-1}}(z_{i-1}-z_{i-2})} \left(\frac{z_{i-1} - z_{i-2}}{z_i - z_{i-1}}\right)^2 \frac{\frac{\tau_i}{\beta_i}(z_i - z_{i-1})}{1 - e^{-\frac{\tau_i}{\beta_i}(z_i - z_{i-1})}} \frac{1 - e^{-\frac{\tau_{i-1}}{\beta_{i-1}}(z_{i-1}-z_{i-2})}}{\frac{\tau_{i-1}}{\beta_{i-1}}(z_{i-1} - z_{i-2})}$$

Using the approximation $1 - e^{-x} \approx x$, the last two ratios are approximately one, so that

$$\frac{\alpha_{i-1}\beta_{i-1}}{\alpha_i\beta_i} \approx e^{\frac{\tau_{i-1}}{\beta_{i-1}}(z_{i-1}-z_{i-2})} \left(\frac{z_{i-1} - z_{i-2}}{z_i - z_{i-1}}\right)^2.$$

To understand the intuition for this spatial aribtrage condition, suppose we increase z_{i-1}. This has two effects. First, it increases the land available to produce good $i-1$.

Second, it raises the rent gradient so that the equality between sectors i and $i-1$ happens at the new location. Both effects increase the total rent paid to sector $i-1$ relative to that paid to sector i. (Hence the quadratic term.) This is inconstitent with equilibrium, where total rents paid to the two sector are determined by the Cobb–Douglas coefficients.

2.8 Circular city

3 Development accounting

3.1 Aggregation across space

Sectoral production, as we show in this section, is a function of a suitably chosen representative location.

Sectoral output measured at the center is

$$\tilde{Q}_i = \int_{z \in Z_i} e^{-\tau_i z} A_i L_i(z)_i^\beta N_i(z)^{1-\beta_i} dz,$$

where Z_i is the set of locations where sector i is active in equilibrium.

Let the representative location

$$\tilde{z}_i = -\frac{\beta_i}{\tau_i} \ln \int_{z \in Z_i} \frac{L_i(z)}{L_i} e^{-\frac{\tau_i}{\beta_i} z} dz \tag{11}$$

denote the average distance of sector i to the center, where $L_i = \int_{z \in Z_i} L_i(z) dz$ is the total amount of land devoted to sector i. This definition ensures that the trade cost going to location $\tilde{z}_i$ equals the land-weighted average trade cost across all sectoral locations,

$$e^{-\frac{\tau_i}{\beta_i} \tilde{z}_i} = \int_{z \in Z_i} \frac{L_i(z)}{L_i} e^{-\frac{\tau_i}{\beta_i} z} dz.$$

As we will see below, $\tilde{z}_i$ is a sufficient statistic about sector location for aggregation purposes.

Proposition 2. *Aggregate sectoral production function is of the form:*

$$\tilde{Q}_i = A_i L_i^{\beta_i} N_i^{1-\beta_i} e^{-\tau_i \tilde{z}_i}. \tag{12}$$

It depends on trade costs from the representative location ($\tilde{z}_i$) defined by equation 11 and is a Cobb-Douglas aggregate of sectoral land ($L_i = \int_{Z_i} L_i(z) dz$) and labor ($N_i = \int_{Z_i} N_i(z) dz$) use.

To show that it is the case, let us express value added (measured at the center) at a location z per unit of land:

$$\frac{e^{-\tau_i z}Q_i(z)}{L_i(z)} = e^{-\tau_i z}A_i(z)\left(\frac{N_i(z)}{L_i(z)}\right)^{1-\beta_i} = (1-\beta_i)^{1/\beta_i-1}A_i^{1/\beta_i}\left(\frac{W}{P_i}\right)^{1-1/\beta_i} e^{-\frac{\tau_i}{\beta_i}z},$$

where we used equation 6 on employment density. From this, total supply of sector i becomes

$$\tilde{Q}_i = \int_{z\in Z_i}\frac{e^{-\tau_i z}Q_i(z)}{L_i(z)}L_i(z)dz = (1-\beta_i)^{1/\beta_i-1}(A_i)^{1/\beta_i}\left(\frac{W}{P_i}\right)^{1-1/\beta_i} L_i e^{-\frac{\tau_i}{\beta_i}\tilde{z}_i}. \quad (13)$$

by the definition of the representative location of the sector in equation 11.

Overall employment in the sector,

$$N_i = \int_{z\in Z_i}\frac{N_i(z)}{L_i(z)}L_i(z)dz = (1-\beta_i)^{1/\beta_i}\left(\frac{P_iA_i}{W}\right)^{1/\beta_i} L_i e^{-\frac{\tau_i}{\beta_i}\tilde{z}_i},$$

so that we can express W/P_i as

$$\frac{W}{P_i} = (1-\beta_i)N_i^{-\beta_i}A_iL_i^{\beta_i}e^{-\tau_i\tilde{z}_i}$$

Substituting this result to equation 13, we obtain the aggregate production function.

3.2 Productivity measurement

Productivity measurements disregarding land and location lead to biased results, which we analyse below using our model. We first show the bias for labor productivity, which ignores land altogether, then for total-factor productivity, which accounts for land, but ignores its location.

Sectoral output per worker is

$$\frac{\tilde{Q}_i}{N_i} = \frac{1}{1-\beta_i}\frac{W}{P_i}.$$

We can substitute out product prices in this formula and express them as a function of input costs. To do this, define average sectoral rents as

$$R_i = \int_{z\in Z_i}\frac{L_i(z)}{L_i}R(z)dz = \beta_i(1-\beta_i)^{1/\beta_i-1}\left(P_iA_i\right)^{1/\beta_i}W^{1-1/\beta_i}e^{-\frac{\tau_i}{\beta_i}\tilde{z}_i} \quad (14)$$

Note that R_i also equals to the rent prevailing at location $\tilde{z}_i$. From this, we get that

$$\frac{W}{P_i} = \beta_i^{\beta_i}(1-\beta_i)^{1-\beta_i}A_i\left(\frac{W}{R_i}\right)^{\beta_i}e^{-\tau_i\tilde{z}_i}$$

so that output per worker can be written as

$$\frac{\tilde{Q}_i}{N_i} = \beta_i^{\beta_i}(1-\beta_i)^{-\beta_i} A_i \left(\frac{W}{R_i}\right)^{\beta_i} e^{-\tau_i \tilde{z}_i}. \tag{15}$$

Log output per worker is

$$\tilde{q}_i - n_i = \beta_i \ln \beta_i + (1-\beta_i)\ln(1-\beta_i) + a_i + \beta_i(w - r_i) - \tau_i \tilde{z}_i$$

Conditional on true productivity a_i, measured productivity (ignoring land) is lower in cities where rents are higher. The magnitude of this bias depends on the (direct and indirect) land share of the sector, β_i. Measured productivity is also lower whenever the sector locates far from the center ($\tilde{z}_i$ is high). The former bias will be bigger for rich countries, as rents tend to be more sensitive to per capita income than wages are. The latter bias will be bigger for rich and urbanized countries, where each urban sector takes up more space. Simply put, services will look unproductive in New York City relative to Budapest, because NYC is larger.

The bias in measured total factor productivity (if location is ignored) depends on sectoral trade costs ($-\tau_i \tilde{z}_i$), as

$$\frac{\tilde{Q}_i}{L_i^{\beta_i} N_i^{1-\beta_i}} = A_i e^{-\tau_i \tilde{z}_i}. \tag{16}$$

The bias is higher in non-tradable sectors, and in large countries and cities.

We can calculate an alternative measure of TFP, valuing the stock of land at market prices (or, rather, market rents),

$$\tilde{L}_i = R_i L_i = R_i(0) e^{-\frac{\tau_i}{\beta_i}\tilde{z}_i} L_i.$$

This ensures that

$$\frac{\tilde{Q}_i}{\tilde{L}_i^{\beta_i} N_i^{1-\beta_i}} = \frac{A_i}{R_i(0)^{\beta_i}} = \frac{W^{1-\beta_i}}{P_i}\beta_i^{-\beta_i}(1-\beta_i)^{-(1-\beta_i)}$$

3.3 Development accounting

Location-corrected productivity can be expressed from measured TFP as

$$a_i = \tilde{a}_i + \tau_i z_i,$$

where $\tilde{a}_i$ is log measured total-factor productivity productivity. This is our main equation for sector-level development accounting.

We are interested in how location-corrected sectoral productivities are correlated with per capita income.

$$\frac{da_i}{dy_i} = \frac{d\tilde{a}_i}{dy_i} + \tau_i \frac{d\tilde{z}_i}{dy_i}.$$

For this, we need a solution to sector-specific location variables as a function of observables.

3.4 Sectoral allocation of land

We want to express the sectoral allocation of land as a function of GDP shares of sectors, which, in contrast to land shares, are observable in NIPA.[4] Land demand per dollar of value added,

$$\frac{L_i}{Y_i} = \frac{\beta_i}{R_i}.$$

Using the formula for the rent gradient,

$$\frac{L_i}{Y_i} = (1-\beta_i)^{1-1/\beta_i}(P_i A_i)^{-1/\beta_i} W^{1/\beta_i - 1} e^{\frac{\tau_i}{\beta_i}\tilde{z}_i}.$$

We rewrite this in terms of land and GDP shares,

$$\frac{L_i}{L} = \frac{Y_i}{Y}\frac{Y}{WL}(1-\beta_i)^{1-1/\beta_i}\left(\frac{W}{P_i A_i e^{-\tau_i \tilde{z}_i}}\right)^{1/\beta_i}.$$

Note that the last term is unit labor cost, and, given that *measured* TFP is $A_i e^{-\tau_i \tilde{z}_i}$, all its components are, in principle, measurable.

Let superscript j denote country j (we have omitted country indexes so far).

$$\frac{L_i^j}{L^j} = \frac{Y_i^j}{Y^j}\frac{Y^j}{W^j L^j}(1-\beta_i)^{1-1/\beta_i}\left(ULC_i^j\right)^{1/\beta_i}, \tag{17}$$

and we have denoted by

$$ULC_i^j = \frac{W}{P_i A_i e^{-\tau_i \tilde{z}_i}}$$

the measured unit labor cost in country j in sector i.

The land share of a sector is increasing in its land intensity β_i (assumed common across countries), GDP share Y_i^j / Y^j (can differ across countries for a variety of reasons), and its unit labor cost. Intuitively, sectors with high unit labor cost use more land to economize on labor.

[4] Value productivity $P_i A_i$ and trade costs $e^{-\tau_i \tilde{z}_i}$ are completely isomorphic in the sense that they only appear together in our aggregate equations. That is, we cannot calibrate τ and $\tilde{z}$ from aggregate data alone. We will calibrate these from ZIP-code-level data in the U.S., and use data on $P_i A_i$ for other countries.

To measure the unit labor cost, we need to choose the units of each sector. To do this, we look at the actual land usage of sectors in the U.S. and choose units in such a way that U.S. unit labor costs are 1 for each sector,

$$ULC_i^{USA} = 1 = (1 - \beta_i)^{\beta_i - 1} \left(\frac{L_i^{USA}}{Y_i^{USA}} \right)^{\beta_i} (W^{USA})^{\beta_i} \tag{18}$$

Having the proper units of output (and ULC), we can simply calculate the land demand in each country for a set of value added shares and measured ULCs.

4 Multiple Cities

So far we have discussed the equilibrium of a given city, with a fixed supply of land and labor. In this section, we introduce a system of multiple cities within a country. We first discuss the case when the number of cities is fixed, but their area and population are endogenous. We then turn to endogenizing the number of cities with development.

To endogenize the boundaries of cities, we have to take a stand on what happens "in between" cities. Following the tradition of the urban literature, we assume that agricultural goods are freely tradable, $\tau_3 = 0$. As we show below, this assumption ensures that agriculture fills up all the space between cities. The urban fringe is then z_2.

When agriculture is freely tradable, its rent gradient is completely flat. Agricultural producers are indifferent as to where they locate.

4.1 Fixed number of cities

Let the country have $k = 1, 2, ..., K$ cities. Each city has a CBD in an exogenously fixed location. We assume the country is large enough that cities boundaries never overlap.

Cities also differ in labor productivity. In particular, city k is characterized by a labor productivity shifter Ω_k, so that the effective supply of labor is $\Omega_k N_k$, where N_k is the population of the city.

We need some heterogeneity across cities to capture the empirical fact that cities differ in size. Desmet and Rossi-Hansberg (XX) build a model where cities differ in productivity, amenities and the efficiency of public services. We focus on productivity to capture the most salient differences across cities. We also note that better amenities are similar to higher labor productivity in that they reduce the unit labor cost in the city: A likeable city offers low wages, making it cheap to produce there.

An *equilibrium system of cities* consists of a list of city populations $\{N_k\}$, city boundaries $\{z_{k2}\}$ XX such that (i) each city is in a *single-city equilibrium* given its boundary z_{k2} and population N_k, (ii) land rents at the urban fringe are equal to agricultural rents, (iii) workers earn the same real wage in each city, (iv) the sum of city population and rural population equals country population.

4.1.1 Equilibrium allocation of workers

Free worker mobility equates real wages across cities. In fact, as the point of consumption is independent from the point of employment (we need this assumption so that agricultural workers can also consume urban goods), the law of one price will prevail for all goods across all cities. This will equate the nominal wage, as well. The only thing that differs across productive and unproductive cities is the urban rent.[5]

4.1.2 Urban sectors

The supply of urban sectors in each city is characterized by the single-city equilibrium, adjusted for city-level labor productivity shifter,

$$Q_m = A_m \Omega_k^{1-\beta_m} e^{-\tau_m \tilde{z}_{km}} L_{km}^{\beta_m} N_{km}^{1-\beta_m}.$$

The rent gradient is modified with the city-specific labor productivity,

$$R_{ki}(z) = \beta_i (1-\beta_i)^{1/\beta_i - 1} (P_i A_i)^{1/\beta_i} (W/\Omega_k)^{1-1/\beta_i} e^{-\frac{\tau_i}{\beta_i} z}.$$

The boundary between the two urban sectors is determined by the relative price, Because the law of one price holds for urban sectors,

4.1.3 Arbitrage at the urban fringe

Urban rent at the fringe z_{km} equals agricultural rent,

$$R_{km}(z_{km}) = R_a = R_{km}(0) e^{-\frac{\tau_m}{\beta_m} z_{km}}.$$

Given that product prices are the same in each city, we can write this arbitrage condition as

$$\Omega_k^{1/\beta_m - 1} e^{-\frac{\tau_m}{\beta_m} z_{km}} = \frac{1}{\beta_m} (1-\beta_m)^{1-1/\beta_m} \frac{R_a}{W} \left(\frac{P_m A_m}{W} \right)^{-1/\beta_m}$$

[5] To be consistent with the free trade of consumption goods, we can reinterpret the CBD as providing a necessary service in the *production*, but not the consumption of goods, e.g., packaging.

Importantly, none of the terms on the RHS depend on k. We can hence derive the relative boundary of any two cities as

$$(1-\beta_m)(\omega_k - \omega_{k'}) = \tau_m(z_{km} - z_{k'm}).$$

More productive cities are larger.

4.1.4 Rural land

We still need to determine the overall quantity of rural vs urban land and employment. The ratio of urban to rural labor,

$$\frac{N_m + N_s}{N_a} = \frac{WN_m/Y + WN_s/Y}{WN_a/Y} = \frac{\alpha_m(1-\beta_m) + \alpha_s(1-\beta_s)}{\alpha_a(1-\beta_a)}$$

is constant. The same ratio for land rents,

$$\frac{\sum_k \tilde{R}_{ks}L_{ks} + \tilde{R}_{km}L_{km}}{R_a L_a} = \frac{\alpha_m\beta_m + \alpha_s\beta_s}{\alpha_a\beta_a}.$$

This suggests the following algorithmic construction of the quilibrium

1. Guess L_a. This also fixes urban land $L - L_a$.
2. Given the relative city sizes and the total urban land, calculate the urban fring for each city $\{z_{km}\}$.
3. Solve for the single-city equilibrium to determine $\{z_{ks}\}$. (XX CHALLENGE: we do not have market clearing by city, they may become specialized in either urban good)
4. Given $\{(z_{ks}, z_{km})\}$, solve for the rent gradient in each city and calculate total urban rents.
5. If urban rents are too high relative to rural rents, reduce L_a and go back to step (1).

4.2 Endogenous cities

Urbanization clearly varies with development (XX REF). We introduce an extension of the model that is consistent with this empirical patterns. The extended model leads to additional predcitions that can be tested against the data.

A country is characterized by a triplet of productivities in the three sectors, (A_s, A_m, A_a), total population N, and total land area L. The country can build cities at a fixed cost f each. Each city has a random labor productivity Ω_k, drawn independently from the common distribution $\Phi(\Omega)$.

An *endgenous-city equilibrium* is XX.

5 Data and calibration

Now we calibrate the model to show that correcting for land and location in sectoral productivity measures has the potential to change previous conclusions of multi-sector development accounting. We allow for sector-specific differences in productivity (A_i), which are the key object of interest in multi-sector development accounting. The urban fringe (z_3) may also vary with country area and its degree of urbanization and we calibrate it below. Demand parameters (α_i) are allowed to vary to allow different countries to have different expenditure shares in agriculture, manufacturing and services. Each country has the same land share within sectors β_i and the same shipping cost τ_i.

5.1 Calibration

First we calibrate land shares and shipping costs using US data. Then we turn to the calibration of parameters influencing cross-country variations.

5.1.1 Land shares

We calibrate sectoral land shares (β_i) using US data. Our aim is to capture the share of immobile factors in production. These come from two sources: (i) the direct use of land in production and (ii) the land-rent paid by workers. We calibrate the direct use of land in sectoral production using US factor income share estimates of Valentinyi and Herrendorf (2008). The first two columns of table 5.1.1 show their estimates for land and labor shares across sectors.

The indirect use of land is the land used by workers. We calibrate land-rent share in labor as a product of the US aggregate rent-share in consumption expenditure reported by the BLS (30%) and the average land-share of US house prices between 1984-1998 estimated by Davis and Palumbo (2008) (36%). We find it to be 10.8%. We multiply this by the labor shares to get the indirect land shares listed in column 3 of table 5.1.1. Our calibrated overall land shares (β_i) are the sum of the direct and indirect land shares, and they are shown in column 4.

The calibrated values show that land is a non-negligible factor in production in each sectors. As expected, its role is the largest in agriculture (23%), but the land share in manufacturing and services are both double-digit (10%-13%), mainly because of the indirect land use of their workers.

Table 1: Calibrated factor shares

Factor shares	Direct land	Labor	Indirect land	Overall land share β_i
Agriculture	0.18	0.46	0.05	0.23
Manufacturing	0.03	0.67	0.07	0.10
Services	0.06	0.66	0.07	0.13

Land and Labor shares are estimates of Valentinyi and Herrendorf (2008). Land share in labor is the product of rent-share in US consumption expenditures, the average land-share of US house prices between 1984-1998 estimated by Davis and Palumbo (2008) and the labor shares. Our land share estimates are the sum of direct land share and the indirect land share in labor.

5.1.2 Shipping costs

We use the 2010 ZIP Business Patters of the U.S. Census to determine the location of sectors in the United States. We use this to calibrate transportation costs and distances of the sectors from the center.

The ZIP Business Patterns contains the number of establishments in employment size categories in each ZIP code for each 6-digit NAICS code. We merge NAICS codes into agriculture, manufacturing and services as follows. Agriculture is sector 11 of NAICS. We merge mining (21), utilities (22), and construction (23) together with manufacturing industries (31-33). As services, we categorize the rest, including public administration. We estimate employment by using the midpoints of the size categories.

To map the model into the data, we need to specify how far each ZIP code is from the city center. We take Urbanized Areas (UAs) as independent monocentric cities, and we assign the central point to the business or administrative center of the first-mentioned city in the UA, as given by Yahoo Maps. For example, the center of "New York–Newark, NY-NJ-CT Urbanized Area" is the corner of Broadway and Chamber St in downtown Manhattan, whereas the center of "Boston, MA–NH-RI Urbanized Area" is 1 Boston Pl. We calculate the distance of each ZIP code to business center of the nearest UA.

According to equation 6, the employment density of sector i in location z is proportional to the rent-wage ratio. When industry i demands positive land in the neighborhood of z, then the rent is proportional to $e^{-\tau_i/\beta_i z}$. We can use this observation

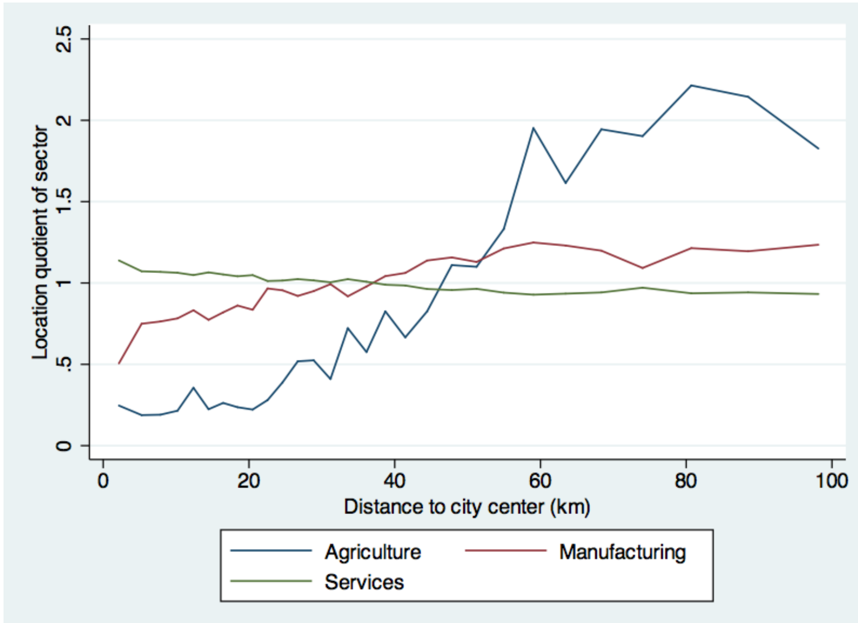


Figure 2: Sector location quotients

Source: ZIP Business Patterns. Plots the sectoral employment shares at a particular distance (in a 3kms wide ring) from the city center, relative to the average sectoral employment share. The figure shows that sectors sort as in the model: services are overrepresented closer the the city center, while manufacturing and agriculture are located mostly farther away, agriculture showing a particularly steep gradient.

to estimate τ_i:

$$\frac{d \ln n_i(z)/l_i(z)}{dz} = \frac{d \ln r_i(z)}{dz} = -\frac{\tau_i}{\beta_i}.$$

To get a sense where each sectors is active, we calculate location quotients by distance to the city center. For each sector, they measure the employment share at a certain distance relative to the average employment share of the same sector. A value higher than 1 implies that the sector is overrepresented in the particular distance from the center.

Figure 2 shows that sectors sort as in the model: services are overrepresented closer to the city center, while manufacturing and agriculture are both underrepresented there. Agriculture shows a particularly steep gradient, with high relative employment farther away from the city center. In the calculation of sectoral employment gradients below, we restrict attention to the areas where the sectors are overrepresented. We assume that services are active up to 30 kms from the center, manufacturing is active between 10 and 60 kms and agriculture farther than 60 kms.

Let n_{izc} be the employment of industry i in ZIP code z, belonging to city (MSA)

c. Assuming that establishments in a given sector consume the same amount of land,[6] we denote by l_{izc} the number of establishments of sector i in ZIP code z. We can then regress establishment size (workers per establishment) in each sector in each ZIP code on fixed effects, and the distance of the ZIP code to the city center,

$$\frac{n_{izc}}{l_{izc}} = e^{\mu_c + \nu_i - \gamma_i d(z,c)}. \tag{19}$$

The city fixed effect captures variation in rents and wages in the MSA, the sector fixed effect captures variation in land and labor intensity and establishment size across sectors. The key parameter of interest is γ_i, which captures how fast employment declines with distance to the center by sector.

5.1.3 Imputing employment density at the ZIP-code level

From the ZBP, we have the approximate employment of the sector (reconstructed from establishment-size bins), and the total area of the ZIP code, but area is not broken down by sector. If a ZIP code is exclusively used by one of the three sector, this is not a problem. Otherwise, we impute the area used by sector i as follows.

The mode predicts the area per worker in sector i in ZIP-code z to be

$$\frac{L_i(z)}{N_i(z)} = \frac{1-\beta_i}{\beta_i}\frac{W}{R(z)}.$$

Because all sectors face the same wages and rents in the same ZIP code, we can distribute land in proportion to

$$\frac{1-\beta_i}{\beta_i}N_i(z).$$

In urban ZIP codes, there is also a substantial amount of residential land. We know that households spend 0.3×0.36 fraction of their income on residential land rent. Assuming that residents' only income are wages,

$$\frac{R(z)H(z)}{WP(z)} = 0.3 \times 0.36,$$

where $P(z)$ is the number of people living in ZIP code z. Hence total residential area is

$$H(z) = 0.3 \cdot 0.36 P(z)\frac{W}{R(z)}.$$

[6] We believe this approximation is likely to bias our estimates of the rent gradient downward. Rural establishments probably occupy more space that urban establishments even in the same narrow industry, so establishment sizes do not go down as fast with distance as employment density does.

We then allocate residential land in proportion to $0.3 \cdot 0.36P(z)$.

We estimate (19) by a Poisson regression which ensures that the equation holds in expectation, and permits estimation even when $n_{izc} = 0$, which is often the case. The estimates of γ_i and the implied sectoral transport cost intensities τ_i in the three sectors are below.

Table 2: Estimated rent and price gradients

		Gradient (per km)	
	Land share β_i	**Rents** γ_i	**Prices** τ_i
Services	13%	13.15%	1.71%
Manufacturing	10%	5.15%	0.52%
Agriculture	23%	3.54%	0.81%

Sectoral rent gradients γ_i are estimated using US employment-density observation across ZIP codes in MSAs. Price gradients reflect transport costs (τ_i) and are estimated by multiplying rent gradients with sectoral land shares (β_i).

The three columns report the calibrated land shares, and the estimates for rent and price gradients, respectively, for each sector. The estimated coefficients can be interpreted as follows. We find that the rents paid by services become 13.15% cheaper with every kilometer from the city center over the 0-30kms range, where services are active. Though a 13% reduction is substantial, it does not seem unrealistic with a whole 1 kilometer distance. In line with our intuition, rent gradients of manufacturing and agriculture (measured further away from the city center) both imply slower rent declines. We infer price gradients reflecting the transportation cost intensities (τ_i) from the measured rent gradients $\gamma_i = \tau_i/\beta_i$ and the sectoral land shares. The last column of table 5.1.3 shows that we find transportation costs of services significantly higher (1.71%) than those of manufacturing and agriculture (0.52%, 0.81%). We hold these estimated technology parameters constant across countries.

5.1.4 Country parameters

We allow three parameters to vary across countries: the sector share of GDP (α_i), the sectoral unit labor costs (ULC_i) and the city sizes (z_3).

To capture the international variation in sectoral demand (α_i), we use sectoral value added shares reported by the World Bank's World Development Indicator database.

The sectoral unit labor costs come from the EUKLEMS database (O'Mahony and Timmer (2009)), which contains internationally comparable sector-level labor compensation measures per hour and labor productivities.[7]

The diverse *size* of the representative cities introduces international variation in transport costs. To control for this, we take the internationally comparable "arable land" measure from the World Bank's World Development Indicator database[8] and divide it by the number of cities with above 50.000 inhabitants.[9] This gives us a measure of the available land in the representative city. As we assume circular cities in our model, this area measure (L) readily translates into distance by $L = z_3^2\pi$, where z_3 the distance of the urban fringe from the city center z_3. Combining these measures with country-level estimates of sectoral land shares, as we show below, we obtain estimates for sectoral transport costs.

5.1.5 Sector locations

International variation in the distances of sectors from the city center influence transport costs. Our sector location measure (z_i^j) is a product of the urban fringe and sectoral land shares:[10]

$$z_i^j = z_3^j \sqrt{\frac{L_i^j}{L^j}}$$

For the US, we calculate sectoral land shares directly using the ZIP Business Patterns of the US Census. For each ZIP area, we calculate sectoral land demand as a share of commercial land, using the published employment data.

Sectoral land share estimates for other countries are obtained using equation 17. The equation considers international variation in both sector demand and unit labor costs. As unit labor costs in EUKLEMS are expressed relative to the US, we choose the units of each sectors such that US unit labor costs are 1 (see equation 18). Table 3 compares estimates for three countries: a large developed country (USA), a small developed country (Belgium), and a small middle-income country (Hungary). Service sector constitute a large share of output in each countries, its share is somewhat smaller in the less developed Hungary. Agriculture, in contrast, generates only 1%

[7]Using multi-factor productivities would reduce our sample size from the already tight 14 to 11.

[8]Some urban land measure would be preferable, but the available measures are based on national definitions, so can not be directly compared internationally.

[9]The dataset is compiled by Stefan Helders (www.world-gazetteer.com) and uses mostly official sources.

[10]In the current version, we are calculating the maximum distance (z_i^j), instead of the average distance ($\tilde{z}_i^j$) suggested by the model. In this way, we are going to get a measure for the maximum bias to productivity estimates by disregarding location. It shows the potential of location correction. In the future versions, we are planning to use the model-based estimates of average sectoral distances.

of the GDP in developed countries, but is somewhat more important in Hungary. Intuitively, sectors are closer to the city center of the representative cities in the smaller Belgium and Hungary than in the US.

Table 3: Calibrated spatial structures

	Share in GDP			**Distance to center (km)**		
	USA	**BEL**	**HUN**	**USA**	**BEL**	**HUN**
Services	77%	75%	66%	36	15	8
Manufacturing	22%	24%	30%	39	16	14
Agriculture	1%	1%	4%	63	21	37

5.2 Development accounting

Which sector's productivity varies more with development? Our estimates for shipping costs and sector locations allow us to create location-corrected sectoral productivity measures A_i from measured productivities $A_i e^{-\tau_i z_i}$. We are interested in their correlation with aggregate productivity. Our measured productivities come from 14 countries in the EUKLEMS database, and we compare them to GDP per capita from the 2007 World Development Indicators. Table 4 presents the estimated elasticities.

Table 4: Elasticity of productivity with respect to GDP per capita

	Measured	**Location-corrected**
Services	0.628	0.855
Manufacturing	0.867	0.926
Agriculture	1.634	1.806

We find that land and location of sectors do influence sectoral productivity measurements. Our preliminary results support previous conclusions that productivity differences in agriculture vary most with development. Correcting for the location-bias, this variation with development is, if anything, even higher. Using measured productivity, services productivity varies less with development than manufacturing productivity, in line with previous result. Correcting for the location-bias, however, changes this picture. It suggests that the cross-country differences in services productivity relative to manufacturing might be overestimated, because in our sample of high and middle-income countries location-corrected services productivity vary *similarly* with development.

6 Conclusion

We conduct sector-level development accounting in a macro model where land and location play a role. Producers in agriculture, manufacturing and services choose their location endogenously to trade off transport costs and rents. We solve for the spatial equilibrium and show space affects the aggregate production function and measured productivity. Studies not accounting for sector location will deem services in large, expensive cities unproductive. This biases development accounting because rich countries have large service-cities. Our preliminary calibrations show that, correcting for sector location, service productivity varies as much across countries as manufacturing productivity does. This is contrast with previous studies that found smaller variation in service productivity.

XX INTERPRETATION: Back to square 1: we still don't know which sector drives productivity differences. 2. Variation might come from macro policies and institutions and may not be sector specific.

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7 Appendix

Table 5: Calibrated spatial structures across countries

	Share in GDP			Distance to center (kms)		
Country	services	manuf	agri	services	manuf	agri
Austria	68.39%	29.86%	1.75%	2.5	2.6	32.4
Belgium	75.40%	23.72%	0.88%	15.7	16.0	20.9
Canada	66.77%	31.55%	1.69%	75.3	75.7	243.0
Cyprus	78.82%	18.97%	2.22%	1.3	1.3	54.2
Finland	63.24%	33.75%	3.01%	10.8	11.0	86.3
France	77.17%	20.62%	2.22%	7.0	8.3	41.1
Germany	68.56%	30.48%	0.96%	43.6	52.2	235.6
Hungary	65.78%	30.19%	4.02%	8.2	14.5	36.9
Italy	70.61%	27.35%	2.05%	2.5	3.6	26.9
Luxembourg	83.42%	16.18%	0.40%	3.2	6.9	28.7
Netherlands	73.24%	24.68%	2.08%	6.6	6.6	13.5
Poland	64.04%	31.64%	4.33%	0.2	0.5	34.0
Slovenia	62.90%	34.60%	2.51%	0.7	2.6	56.6
United States	76.95%	21.92%	1.13%	36.1	39.3	63.5

Table 6: Measured (M'd) and corrected (C'd) sectoral productivities

	services		manufacturing		agriculture	
Country	M'd	C'd	M'd	C'd	M'd	C'd
Austria	0.79	0.45	0.75	0.62	0.32	0.25
Belgium	1.02	0.72	1.25	1.11	0.87	0.62
Canada	1.05	2.04	1.40	1.69	0.58	2.52
Cyprus	1.09	0.61	0.82	0.67	0.13	0.12
Finland	0.75	0.49	1.08	0.94	0.21	0.25
France	0.93	0.57	0.79	0.67	0.44	0.37
Germany	1.02	1.16	0.84	0.90	0.50	2.03
Greece	1.04	0.00	0.58	0.57	0.12	0.09
Hungary	0.55	0.34	0.31	0.27	0.20	0.16
Italy	0.94	0.53	1.01	0.84	0.25	0.19
Luxembourg	1.92	1.10	0.81	0.69	0.52	0.39
Netherlands	1.03	0.62	1.73	1.46	0.61	0.41
Poland	0.75	0.41	0.36	0.30	0.07	0.06
Slovenia	0.62	0.34	0.41	0.34	0.07	0.06
United States	1.00	1.00	1.00	1.00	1.00	1.00

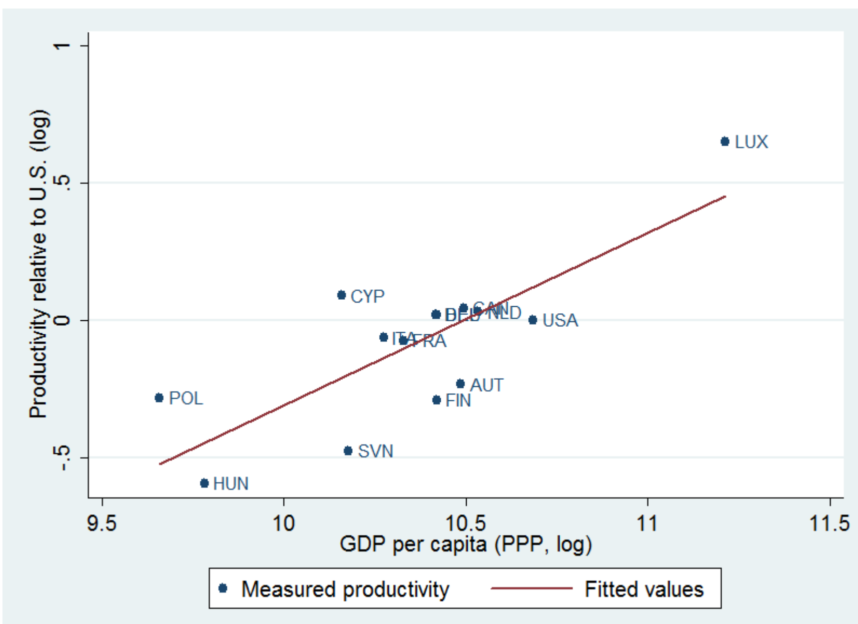

Figure 3: Measured productivity in services

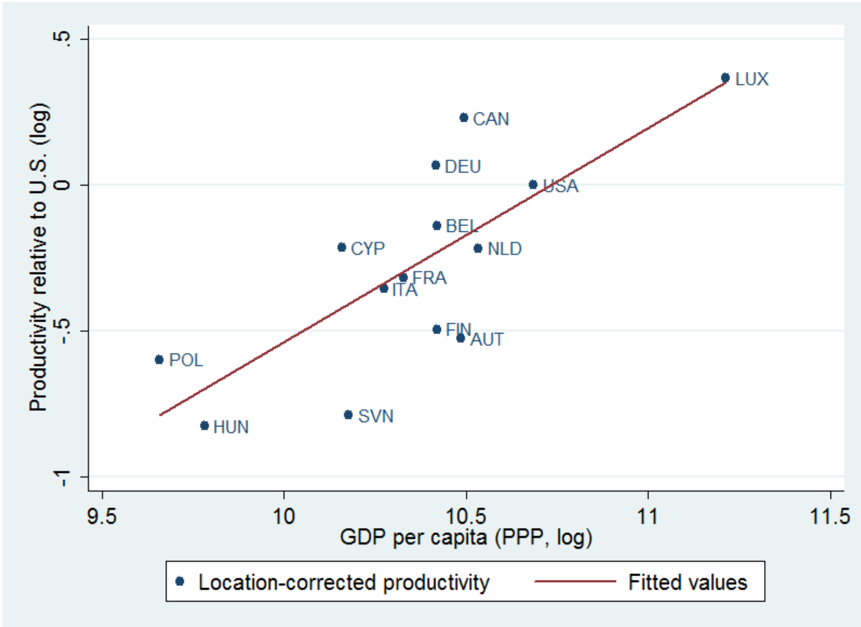

Figure 4: Location-corrected productivity in services

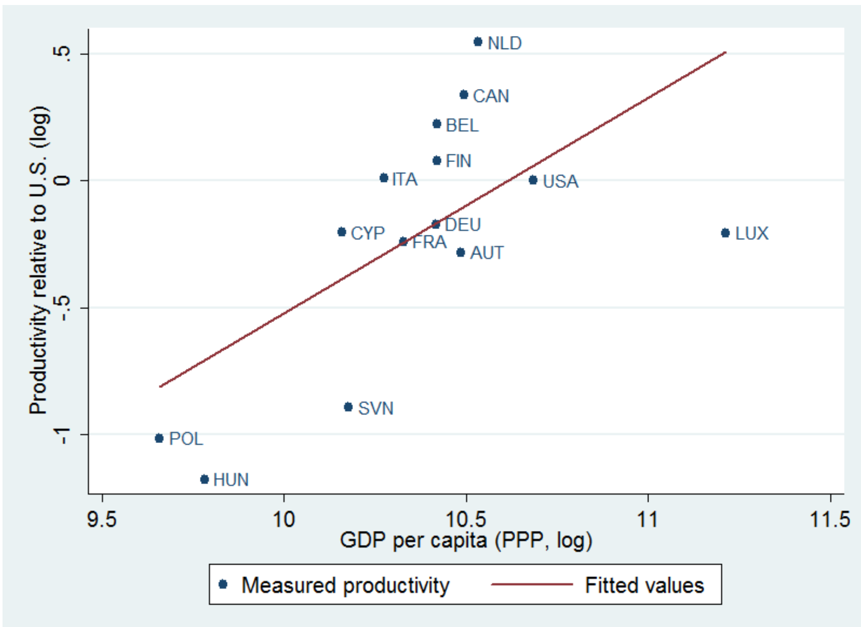

Figure 5: Measured productivity in manufacturing

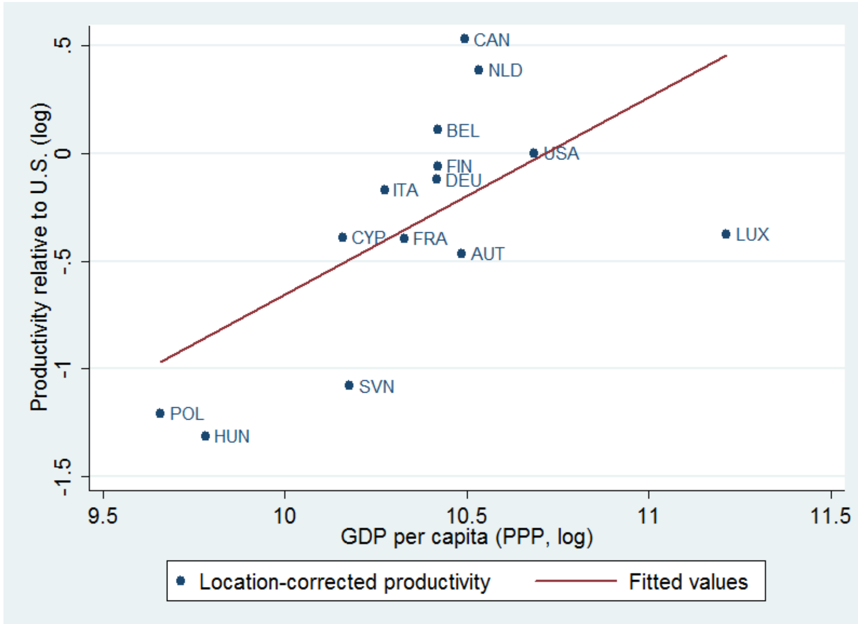

Figure 6: Location-corrected productivity in manufacturing

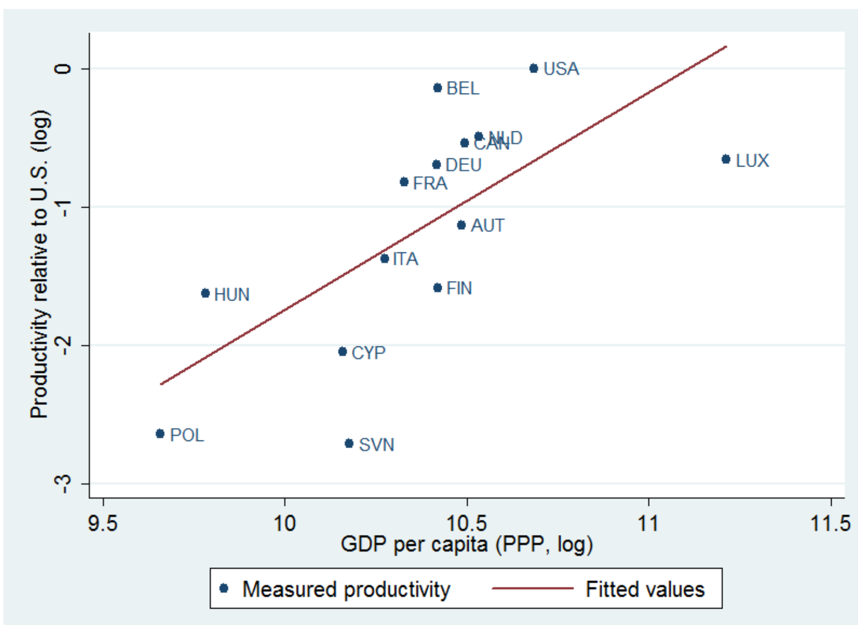

Figure 7: Measured productivity in agriculture

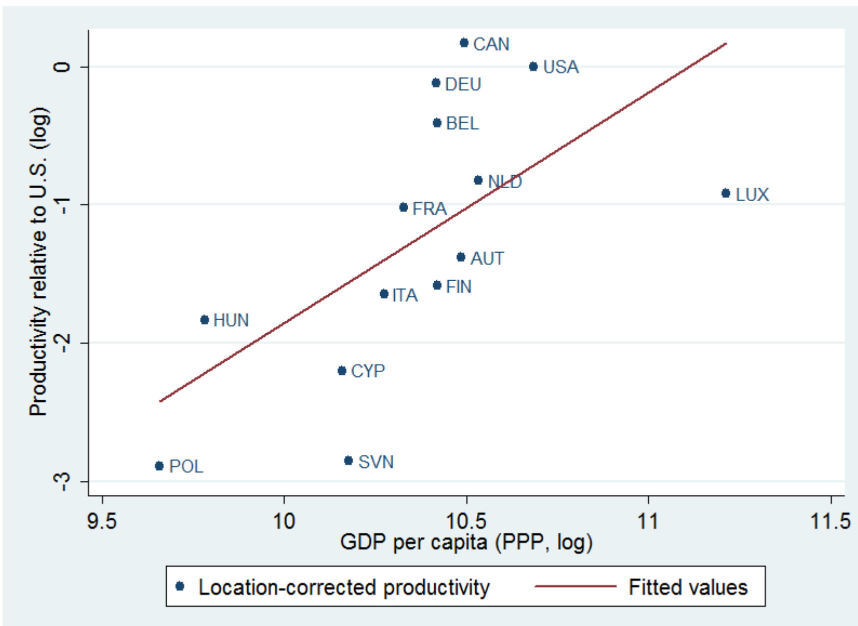

Figure 8: Location-corrected productivity in agriculture