The Effects of Coastal Amenities on the Social Structure of Cities

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One branch of urban economics shows that amenities affect a city's socio-spatial structure, leading to social segregation. Coastal cities comprise a large proportion of the world's population and possess a high level of natural amenities. Therefore, it is important to explore the link between natural coastal amenities and residential segregation. We propose a theoretical model to explain the stylized fact that French coastal towns have American-type social structures. We theoretically explain that there is a small difference in the transport cost ratio between rich and poor households to the CBD and coast.

1. Introduction

According to Rappaport and Sachs (2003), most of the US population and income are clustered in counties located within 80 km of the coastline or the Great Lakes, coastal counties have eight times higher income than inland counties, and they exhibit higher productivity and quality of life. This population concentration is mirrored worldwide: 66% of countries have over 60% of their population living within 100 km of the coast (Martínez et al., 2007). This can be explained by the fact that coastal cities are endowed with a large number of natural amenities that enhance the living environments of their residents (Benson et al., 1998; Landry and Hindsley, 2011).

However, the distribution of natural amenities is uneven across a city, with nearby households benefiting more than those further away. In US cities, Lee and Lin (2018) show that the presence of persistent natural amenities, notably oceans, anchors more advantaged households to their proximity and leads to long-term stability in the spatial distribution of income across neighborhoods. In a French urban region, Schaeffer et al. (2016) show that households' search for natural amenities -including the coast- has a significant impact on location choices and residential segregation patterns. To our knowledge, this link between natural coastal amenities and residential segregation has only been observed empirically, and an urban economic model explaining this relationship is lacking. Previous costal city models (Smith, 1993; Wu, 2001) did not consider household heterogeneity. Besides, such a model could help to explain some (quite surprising) stylised facts for French costal cities, namely that poor households tend to live closer to both the CBD and the coast than non-poor households.

The contribution of this study is thus to propose an open city model with natural costal amenities and to examine how the social structure of the city depends on them. The introduction of the shoreline relaxes the featureless plain hypothesis; each location has two spatial characteristics: distance to the CBD and distance to the coast. We consider the location choices of two types of households, the rich and the poor, in this city. The model is solved using the analytical methodology proposed by Fujita (1989).

Our model exhibits four possible social structures: 'European' (rich in the CBD, poor in the suburbs), 'American' (the converse), 'Rich' (without poor) and 'Poor' (without rich). We can show that the equilibrium social structure depends critically on the difference between two ratios (for the rich vs. the poor) : the ratio of travel costs to the CBD and the ratio of travel costs to the coast. The tendency of poor households to reside nearer to both the CBD and the coast in French coastal cities can be attributed to a higher commuting cost ratio in comparison to the coast-travel ratio.

2. Related literature

In urban economics, most articles related to coastal cities are empirical. They generally estimate household willingness-to-pay for coastal amenities, and very few of them investigated their effects on the urban socio-spatial structure (Lee and Lin, 2018; Schaeffer et al., 2016). A small number of theoretical articles have focused on households' trade-offs between risks and amenities, and their impact on city development (Lin et al., 2021; Walls et al., 2018). Filatova et al. (2009) developed an agent-based model to examine the land market in a coastal city influenced by amenities and disamenities. Simulations showed that the most expensive land was found between the CBD and coast, with a maximum on the coast.

Another branch of the coastal city theory focuses on city development along the coastline. Smith (1993) model studies the effect of the ocean on city development and how coastal amenities influence household choice and rent prices. Wu (2001)'s model also studied city development, but in the context of urban sprawl, he located the CBD one mile from the coast to look at the effect of major geographical features on household location choices and city sprawl. Although both articles proposed analytical solutions, they did not consider household heterogeneity.

The only theoretical study dealing with natural amenities and income stratification does not provide an analytical resolution. Wu (2006) studies the effect of geographical features on community characteristics. He used a theoretical model of urban sprawl with resolution obtained through numerical simulations. This study shows that the heterogeneity of natural amenities leads to economic segregation between households, with wealthier households living closer to amenities. Thus, the aim of this study is to examine the links between the social structure of cities and coastal amenities by following the analytical methodology proposed by Fujita (1989).

3. Stylized facts

We provide a few empirical stylised facts on the social structure of French coastal cities. The question asked is whether the rich or the poor households live closer to the CBD or the coastline.

The analysis is carried out at the level of Functional Urban Areas with over 50k inhabitants, which we consider as cities that have a central employment center. We followed the classification of the French littoral law of 1986 to define coastal communes. The data comes from the "Localised disposable income system" (Filosofi) published by the National Institute of Statistics and Economic Studies (Insee) for 2017. The French territory is divided into a grid of 200m x 200m containing different socioeconomic information on the grid cell, such as the total number of households and the number of poor households.

We examined the spatial distribution of households in French coastal cities in relation to the CBD and the coastline using two indices: the relative centralization index (RCE) (Massey and Denton 1988) and the Environmental Centralization (ECd) (Schaeffer and Tivadar 2019). The values of the RCE and ECd indices are positive (Table 1), meaning that poor households are located closer to the CBD and coast than are non-poor households.

Data	Index	Mean
Poor households	RCE	0.09
	ECd	0.06

Table 1. Average indices

Surprisingly enough, this short empirical exploration shows that the sociospatial configuration of French coastal cities is predominantly of the 'American' type, and (quite in line with spatial and environmental justice requirements) that the poor are not spatially excluded from employment centers and coastal amenities.

4. The model

We follow the general framework of monocentric city developed by Alonso-Mills-Muth. All employment opportunities are located in the central business district (CBD), which is exogenously determined and of a fixed size. Travels within CBD are assume negligible. It provides all supplies of the same composite monetary goods produced by competitive firms. Each household pays rent to the absentee landlord. The city is open, which means that population size is endogenous and the income and utility of the population are exogenous. There is a continuum of locations. We are in a static model; thus, we assume equilibrium. We assume a coastal city characterized by a CBD located on the coast and the need to move to benefit from coastal amenities. This implies that they cannot be enjoyed nearby, and the resident's frequency will always remain the same, regardless of their location in the city (Smith 1993). Each location has two spatial characteristics: the distance to the CBD and the coast. To manage this, we propose two coordinate systems (Figure 1) : Spatial representation of the two coordinate systems):

- geographic space (x, y)
- location choice space : distance from coastline (d_a) and distance from CBD (d)

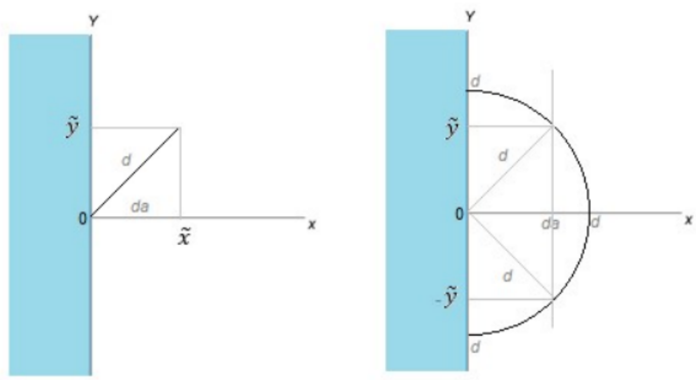

Figure 1. Spatial representation of the two coordinate systems

On the left-hand side of the system, for x and y, we can straightforwardly calculate distances d and d_a:

(1) $$d_a = x \quad and \quad d = \sqrt{x^2 + y^2}$$

Conversely, on the right side, for d_a and d, we can calculate distances x and y as follows:

(2) $$x = d_a \quad and \quad y = \pm\sqrt{d^2 - d_a^2}$$

For one location in the (d_a, d) system, we obtain two locations in the (x, y) system that are symmetrical with respect to the abscissa axis, and the hypotenuse is always greater than that on the adjacent sides $(d^2 - x^2 \geq$

$0 \Rightarrow d \geq x$), the diagonal constraint. There are two types of inhabitants, rich ($i = 1$) and poor ($i = 0$), who choose their location after maximizing their utility level (Eq. 3) under a budgetary constraint (Eq. 4):

$$U_i(z, s) = \alpha \log z + \beta \log s \tag{3}$$

$$Y_i - c_i d - t_i x = z + R(x, d) \tag{4}$$

where $\alpha + \beta = 1$, z is the consumption of the composite good, s is the consumption of housing (surface area), Y_i is the income of household i, c_i is the transport cost to the CBD for distance d, t_i is the transport (or leisure) cost to the coast for distance x, and $R(x, d)$ is the urban rent at a distance (x, d). Households are differentiated in terms of income ($y_1 > y0$), utility level ($u_1 > u_0$), and travel costs ($c_1 \neq c_0$ and $t_1 \neq t_0$). Equations 3 and 4 are used to define the following bit-rent function:

$$\Psi_i(x, d) = \max_s \left\{ \frac{Y_i - c_i d - t_i x}{s} \middle| U(z, s) = u_i \right\} \tag{5}$$

where s is equal to this maximum, $s = S_i(x, d, u_i)$ is the housing demand function. Thus the bid-rent function (Eq. 6) and the bid-max lot size (Eq. 7) are:

$$\Psi_i(x, d) = A(Y_i - c_i d - t_i x)^{1/\beta} e^{-u_i/\beta} \tag{6}$$

$$S_i(x, d, u_i) = \alpha^{-\alpha/\beta}(Y_i - c_i d - t_i x)^{-\alpha/\beta} e^{u_i/\beta} \tag{7}$$

where $A = \alpha^{(\alpha/\beta)}\beta$ and we assume $Y_i - c_i d - t_i x > 0$. Equalizing Ψ_i to a constant bidding (r) (Eq. 8), we obtain what we call *the indifference location curve*: the geometric locus of the location with the same bidding level for a household. This is similar to the indifference curve with the second dimension.

$$\Psi_i(x, d) = r \Rightarrow d_i(x, r) = \frac{Y_i - t_i x - r^{\beta} A^{-\beta} e^{u_i}}{c_i} \tag{8}$$

It is interesting to note that for higher bids, one needs to get closer to the CBD and coast; thus we obtain higher satisfaction with the lower curve (Figure 4). We use a residential model with three competitors for each location: rich households, poor households, and farmers. In equilibrium, the highest bidder occupies each location. Urban rent (rent price) is the upper envelope of the bid rents of the two social categories and the agricultural rent (opportunity cost of land), assumed to be constant in space:

$$R(x, d) = max\{\Psi_0(x, d, u_0), \Psi_1(x, d, u_1), R_A\} \tag{9}$$

The segregation frontier between rich and poor households is where the bids of both are equal. We calcul $\Psi_0(x, d, u_0) = \Psi_1(x, d, u_1)$ and obtain the following segregation function:

$$d^s(x) = \frac{e^{u_0}(Y_1 - t_1 x) - e^{u_1}(Y_0 - t_0 x)}{e^{u_0} c_1 - e^{u_1} c_0} \tag{10}$$

Considering the spatial constraint, $d(x) \geq x \Rightarrow D^s(x) = \max\{d^s(x), x)\}$. This value on the diagonal constraint is defined as $d^s(x) = x$:

$$\tilde{x}^s = \frac{(Y_1 e^{u_0} - Y_0 e^{u_1})}{(c_1 e^{u_0} - c_0 e^{u_1}) + (t_1 e^{u_0} - t_0 e^{u_1})} \tag{11}$$

The city boundary is the geometric place where the bid function of the social category on the periphery is equal to the agricultural rent, we assume $R_A = 0$:

$$\Psi_i(x, d) = R_A \Rightarrow d_i^f(x) = \frac{Y_i - t_i x}{c_i} \tag{12}$$

Considering the spatial constraint, $d(x) \geq x \Rightarrow D_i^f(x) = \max\{d_0^f(x, R_A), d_1^f(x, R_A), x\}$. Thus, the value of the diagonal constraint is:

$$\tilde{x}_i^f = \frac{Y_i}{c_i + t_i} \tag{13}$$

We show that $d^s(x)$, $d_0^f(x)$and $d_1^f(x)$ intersect at the same point:

$$d_0^f(x) = d_1^f(x) \Rightarrow \tilde{x}_{sf} = \frac{Y_1 c_0 - Y_0 c_1}{t_1 c_0 - t_0 c_1} \tag{14}$$

$$\Rightarrow d_0^f(\tilde{x}_{sf}) = d_1^f(\tilde{x}_{sf}) = d^s(\tilde{x}_{sf}) = \frac{Y_0 t_1 - Y_1 t_0}{c_0 t_1 - c_1 t_0} \tag{15}$$

The fact that segregation and city boundaries are unique is made possible by the linear boundary functions. For each x, there is unique segregation and city boundary distance from the center, and vice versa for d. Regardless of x, there are four possible structures.

- European: $0 < d^s < d_1^f < d_0^f$
- American: $0 < d^s < d_0^f < d_1^f$
- Poor: $d^s < 0 < d_1^f < d_0^f$ or $0 < d_1^f < d_0^f < x^s$
- Rich: $d^s < 0 < d_0^f < d_1^f$ or $0 < d_0^f < d_1^f < d^s$

Identical for any d. We can then transpose the location choice space to the geographic space:

$$(16) \qquad y^s(x) = \pm\sqrt{(d^s(x)^2 - x^2} = \pm\sqrt{\left(\frac{e^{u_0}(Y_1 - t_1 x) - e^{u_1}(Y_0 - t_0 x)}{e^{u_0}c_1 - e^{u_1}c_0}\right)^2 - x^2}$$

$$(17) \qquad y_i^f(x) = \pm\sqrt{(d_i^f(x)^2 - x^2} = \sqrt{\left(\frac{Y_i - t_i x}{c_i}\right)^2 - x^2}$$

5. Results

The bid rent function is described as the maximum rent per unit of land that a household can pay to live at a distance (d,x) while enjoying a fixed-level utility u (Fujita 1989). $\Psi_i(x, d)$ shows us that households are willing to pay less as distance from the center and the coast increases (Eq. 18) and bids decrease rapidly with distance, and the distance effect becomes increasingly weaker.

$$\frac{\partial \Psi_i(x,d)}{\partial x} < 0, \quad \frac{\partial \Psi_i(x,d)}{\partial d} < 0, \quad \frac{\partial^2 \Psi_i(x,d)}{\partial x^2} > 0, \quad \frac{\partial^2 \Psi_i(x,d)}{\partial d^2} > 0 \tag{18}$$

Moreover, $\Psi_i(x, d)$ increases in Y_i, and higher incomes enable people to pay more for the same housing if they maintain the same level of utility. If a household wants to increase its level of satisfaction, it must reduce its willingness to pay for housing. We find that the sea influences the shape of the city and has an effect like a "flattening" of the city along the coast (attraction effect), i.e the maximum distance along the coast is greater than the maximum distance to the coast (abscissa axis):

$$y_i^f(0) = d_i^f(0) > \tilde{x}_i^f \tag{19}$$

We saw in the previous section that the poor are located nearer than the rich to the CBD and to the coast in French coastal cities. The American structure appears when (i) there is a small difference between the travel costs ratio (to the CBD and/or to the coast) of the two social categories (rich and poor) and (ii) the utility-level ratio is higher than the income ratio.

Proposition 1: The slope of the segregation boundary is steeper than both city boundaries of rich and poor $|d_0^f{}'(x)| < |d_1^f{}'(x)| < |(d^s)'(x)|$

Proposition 2: Intersection is below the space of possibilities, $\tilde{x}_{sf} < 0$

$$\Rightarrow \frac{t_1}{t_0} < \frac{c_1}{c_0} < \frac{Y_1}{Y_0} < \frac{e^{u_1}}{e^{u_0}} \tag{20}$$

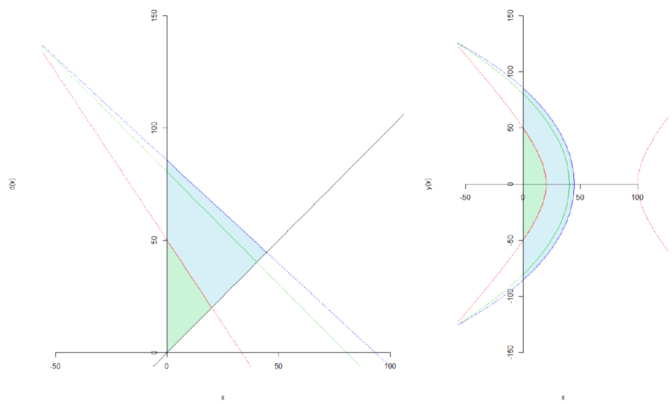

Figure 2. Equilibrium B.1.1

Under these conditions, we obtain Equilibrium B.1.1 (Figure 2) where poor households are close to the sea and surround the CBD, and most of the rich are inland and few close to the sea at the edge of the city. Because the commuting cost ratio is higher than the leisure cost ratio, these rich households choose proximity to the CBD rather than to the coast.

Proposition 2bis: Intersection is in the space of possibilities, $0 < \tilde{x}_{sf} < \tilde{x}_i^f$

$$\Rightarrow \frac{t_1}{t_0} < \frac{t_1 + c_1}{t_0 + c_0} < \frac{Y_1}{Y_0} < \frac{c_1}{c_0} < \frac{u_1}{u_0} \tag{21}$$

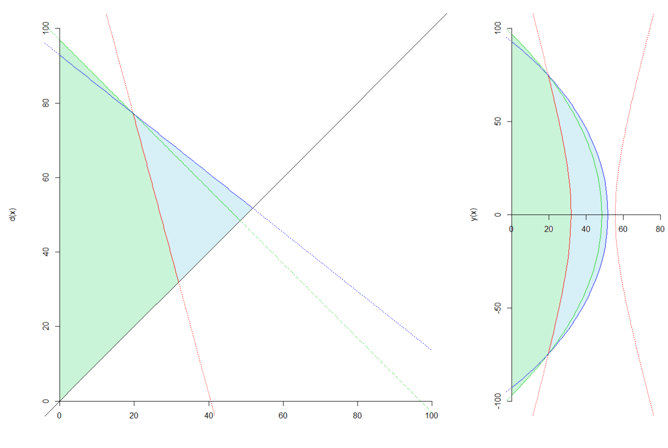

Figure 3. Equilibrium B.2.3.a

We obtain another Equilibrium B.2.3.a under an additional condition (Figure 3). Whether the commuting cost ratio increases and the sea cost ratio is very weak, the commuting cost effect remains the most important.

Poor households occupy the entire length of the coastline. The European structure is the “inverse” spatial situation of the American structure. Under two conditions: (i) a strong difference between the travel cost ratios of the two social categories and (ii) the ratio of income is higher than the utility-level ratio. In some cases, we identified a city with a homogeneous population. A rich town occurs when the income ratio is the highest and has intermediate values above the utility-level ratio. A poor city occurs when the income ratio is the lowest and has intermediate values below the utility-level ratio.

6. Discussion

Solving the model with an agricultural rent involves adding additional conditions on its value. Equalizing it to zero makes it possible to obtain equilibria with one less condition and a clearer formalization of the model. In addition, we cannot consider this as a critical assumption because we focus on the residential aspect. It is interesting to note that the Cobb-Douglas utility function with two components contradicts the Law of Diminishing Marginal Utility in American equilibria. They exist under the condition of the increasing marginal utility of income ($\frac{Y_1}{Y_0} < \frac{u_1}{u_0}$)

Equilibrium B.1.1 is the closest to the situation in French cities. This pattern allows for similar access to the coast for rich and poor households. In other words, both benefits of a comparable level of coastal amenities. This is surprising because the rich have less access to amenities than is expected in the literature. A few cities are closer to Equilibrium B.2.3.a, which we explain by travel costs, but other variables may also be at play. It has been shown that poor households are more likely to live in hazard-prone areas (Walls et al., 2018; Bakkensen and Ma, 2020).

It is important to note that our study has certain limitations. Our modeling choice presupposes a strong assumption that households must travel to the beach to benefit from coastal amenities. The income data we use suffer from imprecision, as fiscal data are blurred in grid cells with fewer than eleven households. An interesting extension would be to consider the frequency of travel to the sea endogenously. Recalculation of the indices using a database at the IRIS level will enable a more precise, albeit geographically less precise, analysis of household patterns.

We show that accessibility to the CBD and sea plays a role in the social structure of coastal towns. Literature shows that wealthier households are more likely to capture natural amenities. Our results can be used by public policies to reduce unequal access to amenities by fostering coastal accessibility.

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8. Appendix

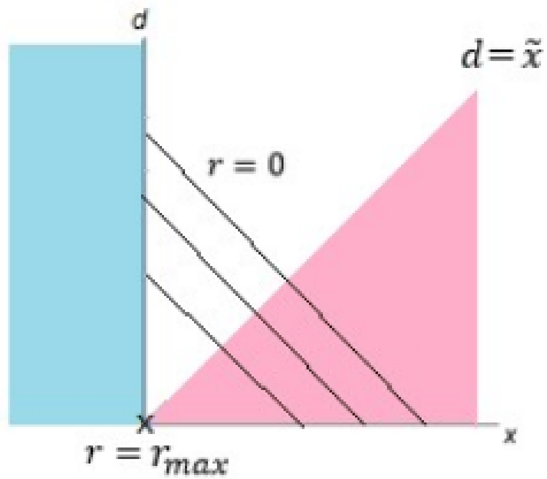

Figure 4. Indifference location curves