Modifying and Applying Hotelling's Model to the Short-Term Rental Market

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Abstract

Standard spatial competition models do not consider an agglomeration effect, a consumer's preference for competing firms to locate near each other. I modify the canonical Hotelling model by adding an agglomeration force and considering quadratic transportation costs. This agglomeration effect posits that consumers derive more utility when firms are located close together. I derive the optimal distance between firms depending on the strength of the agglomeration force relative to the transportation costs. Through data on Airbnb listings, points of wedding venues and transit stops, I develop a regression model to approximate the pairwise firm distance in Boston and San Francisco. I find that Boston's Airbnb listings follow the prediction of the modified Hotelling Model while San Francisco's do not exhibit evidence of an agglomeration force. Based on the interaction terms, I find a higher relative strength of the agglomeration effect compared to transportation cost.

Background & Motivation

Over half of the world's population lives in cities whose structures often dictate the distribution of crucial resources and economic activity. Core to the urban structure are the locations of firms, determined strategically by considering the limitations imposed by regulators, consumer preferences, the decisions of competitors, and transportation infrastructure. I understand a firm's location decision as a strategic game which captures the trade-offs of these firms and helps produce insightful predictions.

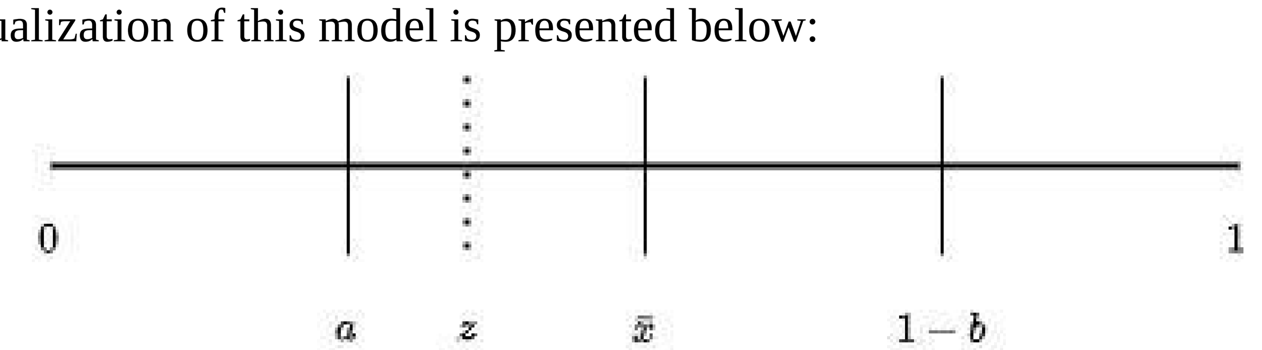
I model the canonical Hotelling model by adding an agglomeration effect, such that consumers derive utility from firm's locating in close proximity. I translate this two-player game into a multi-firm market by comparing distances between pairs of Airbnb listings. Through theoretical modeling and empirical testing, I investigate the intricate relationship between attractive and dispersive forces in determining rental locations.

Theoretical Model

The model is a location model of horizontal product differentiation between two firms, defined as A and B. Each firm selects a location on a line segment and produces a homogenous good. The consumers are uniformly distributed across the line and must choose to purchase from Firm A or B. The consumers, z, maximize utility, comparing utilities from the two firms and considering agglomeration effect, c, and transportation costs, t.

$$U(z;a) = v - t(z-a)^2 - p_A - c(1-b-a)^2$$
$$U(z;b) = v - t(1-b-z)^2 - p_B - c(1-b-a)^2$$

A visualization of this model is presented below:



Theoretical Implications

The socially optimal locations for the two firms are as follows:

$$a^{\star} = \frac{\frac{t}{c}+8}{4\left(\frac{t}{c}+4\right)}$$

$$1-b^{\star} = \frac{3\left(\frac{t}{c}\right)+8}{4\left(\frac{t}{c}+4\right)}$$

Finding the distance between the firms as w:

$$w = \frac{1}{4\frac{c}{t}+1}$$

Data

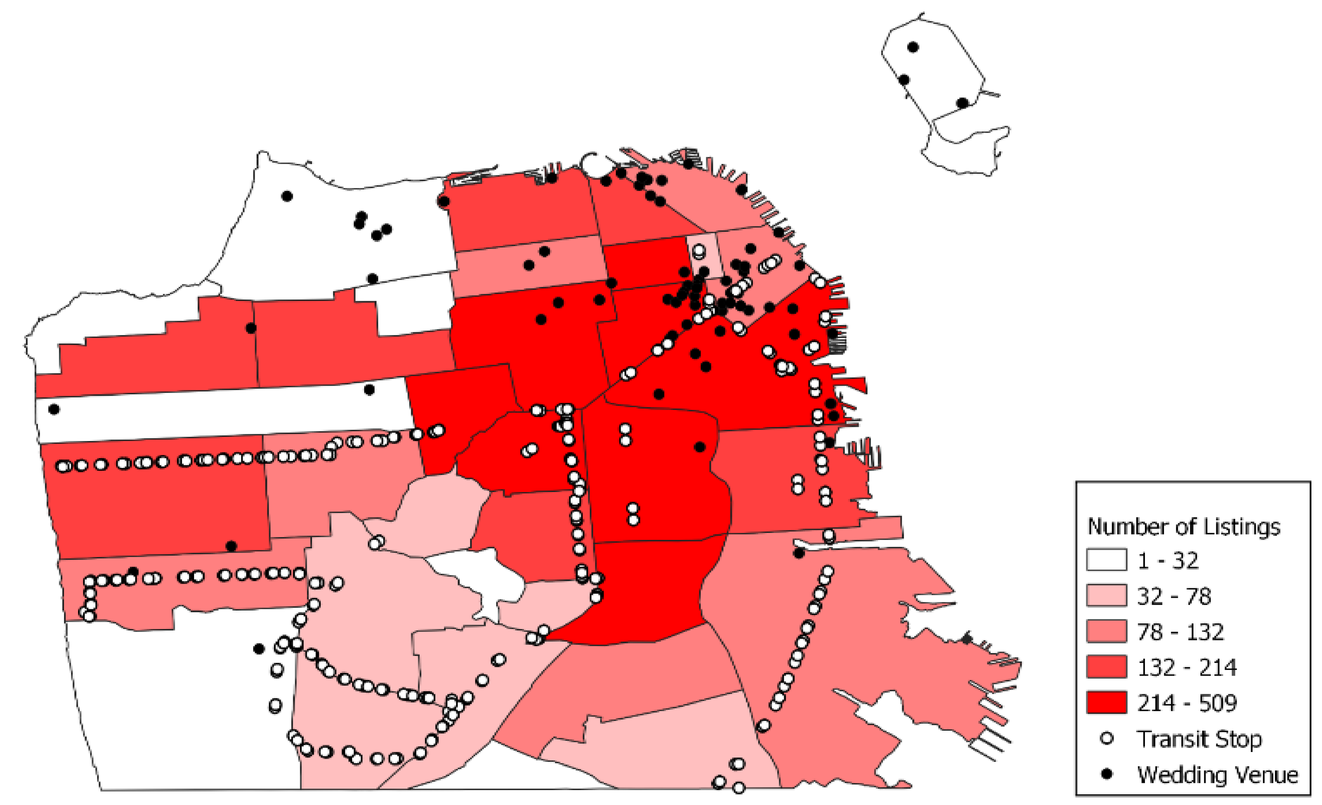
This research uses three data sources:

- Airbnb listing data from Inside Airbnb for San Francisco and Boston from December 2022 to September 2023. 24,707 listings were analyzed.
- Public transit stop locations queried from Open Street Map.
- Wedding venue locations obtained from Rentech Digital, a web scraping tool.

Rationale:

- Airbnb listings represent relatively homogenous goods that are subject to zoning regulations and in line with a zoning assumption.
- Locations of public transit stops indicate relative difficulty of navigating a city where a greater quantity of transit stops corresponds to a lower transportation cost.
- Wedding guests will choose to stay in Airbnbs near each. other in a way that is not fully explained by proximity to an attraction. Presence of wedding venues indicate higher agglomeration effect.

Airbnb Listings in San Francisco by Neighborhood



Empirical Model

I use a basic OLS estimator to identify if distance between Airbnb listings depends on transit stop and wedding venue locations, which serve as the proxy variables for the transportation cost and agglomeration effects.

$$y_{it} = \beta_0 + \beta_1 C_i + \beta_2 T_i + \beta_3 C_i T_i + \theta_t + \alpha_n + \gamma_1 Z_{it} + \varepsilon_{it}$$

- y_{it}: Distance between listing i and its nearest neighbor at time t
- T_i : Distance from listing to closest transit stop
- C_i: Distance from listing to closest wedding venue
- θ_t : Time fixed-effects
- α_n: Neighborhood fixed-effects
- Z_{it} : Vector of listing controls

Results

When Boston and San Francisco are considered in the aggregate, I find significant positive coefficients on the wedding venue and transit stop variables, which align with the theoretical predictions. The interaction term is positive suggesting that the agglomeration effect is stronger than the transportation effect.

VARIABLES	(1) Basic OLS	(2) Interaction	(3) Listings Characteristics
Distance to Nearest Venue	22.671***	8.086***	7.993***
	(0.612)	(2.109)	(2.126)
Distance to Nearest Transit	22.427***	19.100***	19.148***
	(1.712)	(2.475)	(2.498)
VenuesxTransit		10.922***	10.933***
		(2.515)	(2.523)
Time FE		YES	YES
Neighborhood FE		YES	YES

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

When divided by city, the results indicate that Boston exhibited the agglomeration effect but San Francisco did not. Conversely, the interaction term is inconclusive in Boston about the relative strengths of the two contradicting effects.

VARIABLES	(1) Boston	(2) San Francisco
Distance to Nearest Venue	17.130***	-0.072
	(3.054)	(2.369)
Distance to Nearest Transit	64.287***	9.196***
	(11.126)	(2.723)
VenuesxTransit	0.052	13.821***
	(4.243)	(4.266)
Observations	8,610	15,834
R-squared	0.401	0.533
Time FE	YES	YES
Neighborhood FE	YES	YES

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1