Spatial Pricing for Taxi Rides in New York City

**Background.** With an annual revenue of $18.9 billion and annual profit of $1.5 billion, taxi and limousine industry is an essential part of the transportation sector and one of the major segments of the US economy (See e.g., Sayler (2017)). For example, in New York City (NYC), taxis offer over 150 million rides per year (See e.g., TLC (2014)). As opposed to the ideal Walrasian market, in which buyers and sellers interact with the market, customers and taxis search for each other. So, taxi drivers need to be strategic in their search for customers. This search for customers introduces a friction in the market. Regulations and prices set by the taxi industry affect the inter-temporal and spatial distribution of the supply and demand, and the interaction between them, which impacts the consumer surplus and the profit of the drivers. Consequently, various regulatory tools and mechanisms (such as entry restrictions through the introduction of medallions) have been used to improve this interaction. The prices used in the taxi industry, however, rarely change and these infrequent changes primarily intend to keep up with inflation and pay little attention to the distribution of supply and demand, both geographically and temporally.

**Problem Definition.** We propose a pricing scheme in which the fare of a ride is determined by its origin and destination. We refer to this pricing scheme as spatial pricing (not to be confused with dynamic prices). Although spatial prices are not widely used in the taxi industry or ride-sharing platforms, they have the capacity to redistribute both supply and demand. Supply can be redistributed since the profitability of the neighborhoods is closely tied to prices and taxi drivers make relocation decisions with the objective of maximizing their expected profit. The distribution of demand can also be impacted since customers are price sensitive. By impacting both supply and demand, spatial prices provide the policy maker with a unique and powerful tool to intervene in the details of the market.

The equipment that is already installed on taxis paves the way for the implementation of spatial prices. For example, smart meters installed on all NYC yellow taxis (since 2009) report all the information (longitude and latitude of the pickup and dropoff locations) required for the implementation
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of spatial prices. Furthermore, mobile applications such as Arro can inform customers of their fare before they hail a taxi. In this context, we study the following questions: How does the spatial pricing of rides impact the consumer surplus and the profit of the drivers through the re-distribution of supply and demand? What are some important characteristics of the optimal spatial prices? What is the impact of spatial pricing on consumer surplus? How does spatial pricing compare with other mechanisms introduced in the literature such as using Internet-based mobile applications (e.g., Arro and Curb) to achieve a better match between customers and drivers? How does pricing based solely on the origin of the ride compare with pricing based on the origin-destination pair?

Model. We propose a finite-horizon mean field model for the taxi market. This model captures the interaction between supply and demand during the day shift on weekdays in NYC. The model ensures that the supply of taxis across the city is consistent with the flow of empty and full taxis and captures the forward looking behavior of the drivers in their search for customers. The taxi drivers make relocation decisions with the objective of maximizing their expected profit. The model allows for spatial and inter-temporal variations in the arrival rate of price sensitive customers, and uses an aggregate matching function that captures the spatial friction in the search for customers.

We use the dataset of all taxis rides occurred in NYC in the span of 2010-2013. For each ride, information on the pickup/dropoff time and location, the fare paid by the customers, and the taxi that offered the ride is available. We use this dataset to estimate the primitives of the mean field model. These primitives include the parameters of the graph of NYC, the demand model, the variance of the cost shocks incurred by the drivers, and the initial distribution of the taxis.

Contributions. Our work combines mean field models, that are used for analyzing settings where an infinite number of rational decision makers take actions to maximize their individual objectives, with empirical estimation. This allows us to take advantage of the power of mean field models and discuss the implications of spatial pricing in the biggest taxi market in the US (NYC).

Using the estimated primitives, we run counterfactual analyses to estimate the impact of spatial pricing on various performance measures. Counterfactual analyses allow us to compare the
performance of the taxi industry in NYC if spatial prices were to be used with its performance under the current prices. They also allow us to compare the performance of spatial prices with the performance of other mechanisms introduced in the literature, such as using mobile applications for better matching taxis and customers locally. We observe that a suitably optimized spatial pricing scheme, which prices rides based on their origin-destination pair and allows prices to change between 50% and 150% of the current prices in NYC, can serve up to 18% more customers (39,000 more customers in each shift), without hurting the drivers’ profit. Similarly, a suitably optimized spatial pricing scheme that only uses origin information can serve up to 12.9% more customers (27,300 more customers in each shift). Spatial pricing results in a 12.5% increase in the customer miles (sum of the miles traveled by all served customers), which indicates a considerable increase in the utilization of taxis. This is achieved by providing incentives to drivers to relocate to locations that are under-served, which increases the total number of customers served.

Similar patterns hold for spatial prices that maximize consumer surplus. Our results show that the intensity of demand, average fare paid by the customers, and price-elasticity of a location are among the major factors determining the optimal price of the location (when maximizing the total consumer surplus). Local supply and demand alone no longer determine prices at a location. Rather, spatial dynamics, such as the expected total fare that a taxi receives by relocating to the location, drive pricing. This leads to prices that are substantially different from what surge pricing (pricing based on local and temporary imbalances in supply and demand) alone would suggest.

**References**


Brian Sayler. IBISWorld industry report 48533 taxi & limousine services in the US. 2017.