

# **Dynamic Pricing Under Competition: An Empirical Study of the Hospitality Industry**

Alex Nikulkov, Kostas Bimpikis, Yonatan Gur

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## An Empirical Study of the Hospitality Industry

Dynamic pricing policies have traditionally been studied in the context of a monopoly. However, in most practical dynamic pricing problems, demand depends on prices selected by competitors, leading to dynamic interactions among firms. We study how such competition may impact the performance of dynamic pricing policies through an empirical analysis of a unique data set from the hospitality industry.

We model the problem of sequentially pricing perishable goods in the presence of competition as a dynamic discrete-time game between competing firms. At the beginning of the game each firm has some initial inventory, and this inventory is reduced as the product is sold. At each epoch each firm is choosing a price after observing its own remaining inventory, as well as the inventory levels of its competitors. All firms know the parameters that describe all demand distributions. Customers are assumed to be short-lived, in the sense that demand in each period depends only on contemporary prices. The demand of each firm is decreasing in its own price and increasing in its competitors' prices.

The equilibrium price of each firm depends on the state of the dynamic game, which includes the inventories of all firms, creating the dependence of optimal price on competitors' inventory levels. The potential impact of adopting dynamic pricing policies (relative to static pricing policies) in a competitive environment is two-fold. On one hand, dynamic pricing policies may increase firms' revenues by allowing them to adapt to changing market conditions (see Gallego and Van Ryzin 1994). On the other hand, dynamic pricing policies may decrease revenues by intensifying competition. We provide examples, which show that both cases are possible, but that dynamic pricing typically decreases revenues when customers' price sensitivity is low. To analyze the effect of dynamic pricing, we use alternative pricing strategies as benchmarks for comparison. We consider two possible benchmarks: (1) pre-committment

to particular price paths chosen by each firm simultaneously at the beginning of the selling horizon and (2) dynamic pricing policies restricted to using only the firm's own inventories as inputs for its pricing strategy.

Only a few papers have studied dynamic pricing in the presence of competition. In particular, Levin et al. (2009) consider a setting of an oligopoly pricing dynamically in the presence of forward-looking customers, but their main focus is on the impact of forward-looking customers, rather than competition; and Gallego and Hu (2014) consider a pricing game between several competitors, prove the existence of a dynamic pricing equilibrium and explore its structure, but do not analyze the connection between competition and dynamic pricing. Our paper differs from the line of work mentioned above in two key aspects: we analyze the effect of intensification of competition by dynamic pricing and we apply our model to a unique data set from the hospitality industry.

A major component of our work is an empirical study, based on a data set that was collected from the hospitality industry. The data set includes quoted room prices for 3321 hotels in 10 major US cities during 4 months (arrival dates in December 2013 – March 2014). If a hotel has multiple room types, each type is observed separately. For each arrival date, we observe quoted prices during last 90 days before arrival date. For some hotels we also observe room availabilities on each day, which allow us to infer sales by taking first differences of availabilities in consecutive time periods. We only observe the aggregate changes in room availability, which are equal to the difference of bookings and cancellations. Since we do not observe cancellations separately, we assume that cancellations are rare and inventory changes are equal to sales. The empirical model includes a demand side, estimated as a quasi-Poisson generalized linear model using room availabilities as instruments for prices (to control for endogeneity of prices), and a supply side, which rationalizes observed prices using generalized method of moments with first-order optimality conditions as moments. Assuming that hotels face the strongest competition from other hotels that are located close by and have similar average price, we use a clustering algorithm based

on location and average price to divide hotels into smaller “sub-markets” and assume that competition occurs only within these sub-markets. This assumption allows us to greatly reduce the dimensionality of the problem and avoid overfitting the demand model.

We find that in some cases following dynamic pricing policies under competition can reduce the revenues of all competitors, compared to pre-committment pricing rules. This can be explained by negative externalities, which competing firms impose on each other when using dynamic pricing. These externalities are due to an increased frequency of competitive interactions and dependence of optimal prices on inventory level of all competing firms.

## References

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