



Innovative Applications of O.R.

The hidden information content of price movements ☆

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ABSTRACT

Dynamic patterns of prices in different markets may motivate (strategic) consumers, who could be monitoring price movements over time, to game vendors. Do past price movements carry information about the probability and magnitude of future price drops?

Conducting empirical work in the airline industry on near 1000 US domestic routes, we find that some price-metrics carry information about future price swings: these variables can assist in predicting the likelihood and magnitude of price drops. These price-metrics yield significantly different signals which also vary as the prediction horizon changes.

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1. Introduction

Dynamic pricing and revenue management (DP/RM) practices have been adopted in many markets, such as air travel, hospitality, and some retail markets like rental vehicles and intercity rail markets. The prices posted by vendors fluctuate over time to reflect, and, hopefully, profit from, the arrival of different types of consumers. In the air travel, auto rental and hotel industries, for example, prices tend to increase toward the usage/consumption date, as vendors expect business travellers to make their travel arrangements close to the travel date or make last minute bookings; on the other hand, in the charter sector of the airline industry, prices tend to drop as the consumption (departure) day approaches.¹

Vendors whose prices dynamically change over time, strive to keep ahead of consumers, many of whom struggle to decipher the system and attempt to time their purchase so as to find a lower available price. Pricing in the presence of such consumers, who are often being referred to as strategic consumers, has received increased attention (see, e.g., Shen and Su, 2007; Levin et al., 2008; Jerath et al., 2010; and the review by Aviv et al. (2009)). When stra-

tegic consumers weigh their options, they endeavour to predict the probability the price will drop and by how much versus the potential risk that only higher prices will prevail or even that the product will not be available within the consumers' consumption time horizon. In line with this literature, we study, in this work, how the past behaviour of prices could help such consumers in refining their waiting and purchase decisions. Specifically, we are interested in exploring whether price-metrics of dynamically priced and revenue managed goods or services carry information about the probability and magnitude of future price drops.² Airline markets provide a wealth of readily accessible data to investigate the behaviour of prices over time and allow us to examine whether the behaviour of past prices contains useful information about future price drops; it is in these markets that our empirical research is focused.

Goods can be dynamically priced, or, alternatively, prices in markets may exhibit variable, or volatile, behaviour for various reasons, such as inventory and uncertainty considerations, as is explored primarily in the operations literature (Gallego and van Ryzin, 1994), or realizations of mixed strategy Nash equilibria, due to, for example, information asymmetries or search frictions (Varian, 1980), price discrimination practices (Narasimhan, 1988), or competitive manipulation of prices (Bass et al., 2006).

Demand uncertainty, price discrimination and inventory considerations are key factors in the realization of prices in airline

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¹ Many European airports, for example, have sections in the terminals containing collections of airlines selling inexpensive last minute vacation deals.

² An earlier version of this paper, which is available upon request from the authors, studies price increases as well.

markets. Roughly speaking, to facilitate discrimination among customer groups, the airlines' revenue management systems post lower prices far from the departure date so as to capture the demand from leisure passengers, and as time progresses, they post higher prices aimed at customers with less flexibility and late booking price insensitive business passengers. Airlines generate booking curves for each flight, which outline the predicted progression of bookings for each flight and adjust prices in accordance to the actual versus expected bookings. When demand falls short of the booking curve, airlines usually drop prices, while excess demand, naturally, triggers a spike in prices.

Airlines could also be intentionally fluctuating prices as a mechanism to induce a purchase decision. Understanding consumer behaviour, airlines may be constantly changing prices as a tool to manipulate consumer behaviour, as price volatility affects the range of prices that consumers consider acceptable for a given product (Rao and Sieben, 1992; Kalyanaram and Little, 1994). In effect, faced with uncertainty about prices, consumers find it harder to judge which prices are fair or reasonable (Boyd, 2007). It is commonly assumed that consumers can be segmented into two distinctive groups: myopic, who passively react to the price adjustments, and strategic, who seek to optimally time their purchase in the presence of dynamic pricing mechanisms (see, e.g., Cachon and Swinney, 2009).

In this paper we empirically investigate airlines' dynamic pricing mechanisms by unlocking hidden relationships between past and future prices. Specifically, the paper examines how observed price levels and volatilities, after controlling for market structure, could reveal information about the probability of encountering lower prices in the immediate (next 3 days) or near future (next 7 days) or during the entire time remaining before the flight departure. Of equal interest is the magnitude of this price drop and how this relationship changes as the travel date approaches; we separate the terminal two weeks prior to departure from the rest of the selling horizon (i.e., business vs. leisure travellers).

Our analysis implicitly assumes that consumers observe prices for some time (at least a week) and have an assessment of price level and volatility for the market they are considering. Conducting an extensive empirical analysis on close to 1000 US domestic routes, we find that these price metrics could be used in improving predictions about future swings of prices. Focusing on price drops, we highlight several important insights: (i) some of the price metrics emerge as significant indicators for price drops and the magnitude of the decrease. For example, our higher relative price metric (the current price vs. recently posted prices) consistently signals the price is likely to drop, while more volatile prices indicate greater savings ahead. This may further support an argument that airlines could be artificially inflating and fluctuating prices (possibly to alter consumers' expectations/perceptions); (ii) the behaviour of the price metrics changes as different waiting time horizons are considered. For instance, the coefficient of relative price roughly doubles for longer time horizons; (iii) and the behaviour of the price metrics changes as the departure date approaches.

Hence our research complements the growing body of literature that studies pricing in the presence of strategic consumers by contributing empirical insights on the type of inferences that such consumers (and retailers alike) could make by observing prices for some time. We further complement the existing empirical literature on price dynamics and price volatility, which primarily aims at measuring the degree of price variation and investigating their sources, in that we further look into the hidden information that various price metrics, regardless of their source, may disclose.

The paper is organized as follows. In Section 2 we review the literature on dynamic pricing, consumer behaviour, the interaction of retailers and strategic consumers, and empirical studies in the con-

text of fare setting by air carriers. Section 3 develops the main research questions about the relationship between past and future price movements, while Section 4 elaborates on the collection of data and definitions of the variables used in the empirical study. In Section 5 we outline the different models we test and their empirical results. Section 6 contains the conclusions.

2. Background

Airlines frequently update the set of airfares they offer in their ongoing efforts to maximize revenues from their network of flights. These efforts are automated through the implementation of dynamic pricing and revenue management (DP/RM) systems.³ A rich literature has emerged which investigates different aspects in the implementation of these systems. This has long attracted the attention of the operations literature (see, e.g., the special issue of *EJOR* on RM/DP (Levin and McGill, 2009)). Contributions, such as Talluri and van Ryzin (2004) and Boyd (2007) provide excellent descriptions of the theory and practice of DP/RM. Further reviews include, e.g., McAfee and te Velde (2007) and Shen and Su (2007).

Faced with dynamic pricing mechanisms, consumers may adapt to the changing behaviour of prices; becoming strategic. Modeling the interaction between strategic consumers and retailers can be traced back to Coase (1972) and Stokey (1979, 1981), which was later refined by many such as Gul et al. (1986) and Besanko and Winston (1990). Studying decisions in the presence of strategic consumers is gaining increasing popularity in the operations literature (e.g., Aviv and Pazgal, 2008; Levin et al., 2008, 2009; Su, 2007; Dasu and Tong, 2010). In particular, Anderson and Wilson (2003) have demonstrated numerically the impact strategic consumers, who are familiar with the airlines' revenue management mechanisms (i.e., the expected marginal seat revenue, EMSR), could pose on airlines. In this paper, rather than adopting strong assumptions about consumers' knowledge and information, we argue that consumers may be able to reach some inferences about future price movements after they have been observing prices for some time and we demonstrate this empirically.

In the context of strategic consumers, Jerath et al. (2009) identified empirical studies of airlines' revenue management systems as a fruitful area for future research. To explore the changing prices as commanded by the DP/RM systems, one needs to actively collect prices (in our case from the Internet). The various work in this emerging area examine, among other issues, the progression of prices about the departure date, the rise/fall of prices, the price of substitutes, differences in inter-temporal price discrimination between legacy and low cost carriers and price dispersion across fare histories (see e.g., McAfee and te Velde, 2007; Pels and Rietveld, 2004; Piga and Bachis, 2007). Tretheway and Kincaid (2005) review empirical studies in the context of airline pricing.

Gillen and Mantin (2009) characterize price volatility in airline markets. While they study the determinants of price volatility, in this work we seek to explore whether price volatility could serve consumers as a tool for extracting information about future price drops. The notion of price volatility is closely related to similar studies in finance. Beckers (1981), for example, looked at transactions prices to study the value of implicit standard deviations in predicting future prices volatility. Taylor (2005) examines three prediction problems; which way will prices move; how volatile will prices be and, what does the probability distribution of prices look like several periods into the future. Empirically analysts look at option prices and future contracts but they do not examine

³ We recognize such systems are not 100 percent automatic and fares are reviewed periodically by fare managers.

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