Organizational Form, Information Asymmetry, and Market Prices.*

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Abstract

Vertical integration can affect the information structure of firms in the downstream market. In the hotel industry, properties managed by headquarters have increasingly more precise information about uncertain market demand. We develop a simple model of pricing under incomplete information where decision makers are uncertainty averse and use decision making rules that are robust to uncertainty. The model predicts that franchised hotels reduce prices by a larger amount than chain managed properties in the same market in the lead up to the date of stay. Empirical evidence from over 800 properties across the US belonging to 6 brands, over three different time periods, shows that franchised hotels exhibit a negative relative price trend, consistent with the predictions of the model. Alternative explanations arising from other consequences of variation in organizational form, including joint pricing across chain managed properties in the same market, are unable to explain these findings. In this setting of information asymmetry and uncertainty aversion, heterogeneity in organizational form in an oligopolistic market is associated with lower price levels in both integrated and non-integrated downstream firms since prices are strategic complements.

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1 Introduction

When vertical integration of upstream and downstream activities means decisions are made to maximize joint profit, the integrated firm can affect downstream market outcomes through the relative prices and quantities of downstream market inputs and also by behaving strategically.[1] In this paper, we suggest that vertical integration can also affect the information structure of the downstream market. We examine the implications of information asymmetry between integrated and non-integrated firms for downstream market prices. The empirical setting is the hotel industry, where branded properties can be chain managed (integrated) or franchised (non-integrated). We explore – both empirically and theoretically – how hotel pricing is affected by organizational form when franchised and chain managed properties differ in their uncertainty about market demand.

Hotel properties affiliated with a brand are part of a common reservation system. In the days leading up to a date of stay, revenue managers at chain managed hotels observe the share of reserved rooms at all branded hotels. Revenue managers in franchised hotels observe only their own occupancy rate. We argue that this differing access to information about reservation rates in the market creates an asymmetry in revenue managers' understanding of market demand within markets where there are both franchised and chain managed properties. Revenue managers in chain managed hotels have an increasingly more precise estimate of demand, and may also have more resources to process this information. When revenue managers are uncertainty averse, we show that this asymmetry leads franchised properties to set a negative relative price trend.

We first investigate the price trends observed in property-level data. We focus on how dynamic pricing varies with organizational form studying only the supply side of the market. Restricting the focus to price changes rather than levels allows us to include property-level fixed effects and avoid the most troubling issues surrounding organizational form endogeneity discussed in the studies of prices in this industry by Vroom and Gimeno (2007) and Kosova et al. (2007). Since demand is independent of organizational form in this setting – buyers are typically unaware whether a hotel is chain managed or franchised – we circumvent many of the challenges associated with unobservable

[1] Forbes and Lederman (2009) draw a distinction in the empirical literature between incomplete contracting theories of vertical integration where input levels, such as managerial effort, depend on whether the downstream activity is integrated and hence controlled by headquarters, and strategic market power based theories where vertical integration may prompt upstream firms to, for example, foreclose competing downstream firms. Gilbert and Hastings (2005) find evidence that integrated gas refiners raise input costs to competing retailers. Hortacsu and Syverson (2007) find little evidence of foreclosure in their study of ready-mix cement. Non-strategic behaviors affecting input and hence output prices include double marginalization or multiproduct pricing across vertically integrated downstream units. Forbes and Lederman (2009) also note that direct empirical evidence about the consequence of variation in organizational form is relatively rare.

demand addressed in existing studies.[2] In particular, our model is independent of whether consumers are strategic in their decision about when to make a reservation as in Liu and van Ryzin (2008).

These two features of the research design motivate our use of a difference-in-differences empirical approach. Data from six hotel brands in the US reveal that franchised properties cut prices faster than chain managed hotels in the lead up to the date of stay. This finding holds for three different time periods during 2008 and 2009, and the inclusion of relevant property and market level controls. That is, revenue management varies in this industry with organizational form.

We next develop a theoretical framework to investigate potential causes of the negative relative price trend for franchised hotels. In contrast to the market for baseball tickets studied in Sweeting (2008), the sellers in local hotel markets are likely to exert market power. We construct a simple two-period pricing game with two players and asymmetric information. In Bergemann and Schlag (2008), an uncertainty averse monopolist who is uncertain about a buyer's valuation uses a maximin decision rule when setting price, based on the axiomatic approach in Gilboa and Schmeidler (1989). The price set by the monopolist is a decreasing function of uncertainty about the buyer's valuation.

We use a similar decision making structure in our two player, two period game, and construct a unique subgame perfect equilibrium for prices. One player is a franchised hotel and the other is a chain managed hotel. Both properties reduce prices in the second period since there is no longer an opportunity cost associated with reserving a room on that day. When facing uncertainty about the true nature of demand, both properties use a robust pricing rule which is a function of the precision of their information about demand. There is a reduction in the relative uncertainty for the chain managed property in the second period and although both properties understand that there is an asymmetry, the franchise does not know the extent of the chain's increase in information precision. In contrast, the chain has full knowledge about the franchise's information. The chain reduces prices by less than the franchised hotel in the second period. In the equilibrium, franchised hotels exhibit a larger negative price trend.

The model predicts that the greater the information asymmetry the larger will be the difference in price trend for the relatively uninformed party, i.e. the franchised hotels.[3] There is variation across geographic markets in the number of franchised hotels contributing to the brand booking system, which we suggest will cause variation in information asymmetry across markets. A triple differences analysis of the variation in relative price trend in different markets reveals that franchised

[2] There is a large literature in operations management on dynamic price of fixed inventory models with unknown demand, see Gallego and van Ryzin (1993).

[3] The model also predicts that chain managed hotels will set higher price levels in the second period, all else equal. This proposition is harder to test in the data due to the endogeneity of organizational form.

hotels in markets where the information asymmetry is particularly large cut their prices significantly faster.

Other consequences of vertical integration have different predictions for the relative price trend. Vertically integrated properties in the same market are effectively horizontally integrated, and so we might expect prices to be set to maximize joint profits. All else equal, this suggests chain properties will set higher price levels than franchised hotels. Turning to price trends with joint price setting within chain managed properties, a three hotel model of dynamic pricing with no uncertainty aversion shows that under reasonable restrictions on the relative magnitudes on the parameters of the demand function, the chain managed properties are predicted to cut prices by more than the franchised property in the second period. This is due to the fact that prices are strategic complements.[4]

We look for evidence of alternative explanations for the negative relative price trend observed in the data. Non-integrated properties pay royalties to headquarters which is predicted to raise their price levels through a double marginalization-type effect but has no predictions for price trend since the percentage royalty rate is independent of when the room is reserved. Other theories of vertical integration might suggest non-integrated properties are either less or more able to adapt to locally changing demand conditions and this may explain the findings in the data, given the unfavorable economic environment faced by the hotel industry in 2008 and 2009. However, there is no evidence that the frequency of price change varies with organizational form, or that the relative frequency of making a price change differs as the date of stay approaches. Vroom and Gimeno (2007) suggest that chain managed hotels are more able to commit to not lowering price levels to maintain brand reputation over time. Two aspects of the findings, while consistent with our model, create doubt that these reputation effects explain the observed differing price trend. We show that franchises cut price particularly fast when in markets with many other same-brand franchises, controlling for the size of the market and the number of same brand properties. Second, in one of the three data sets all hotels are actually increasing price levels but franchises are increasing at a slower rate.

In this paper, we draw on the growing literature in mechanism design of robust decision making when there is uncertainty about the true model. Bergemann and Schlag (2008), in their study of the monopoly pricing problem under incomplete information, show that robustness can be guaranteed by considering decision making under multiple priors. One of the two approaches they use to

[4] The appendix sets out the equilibrium for the three hotel case with no uncertainty aversion. Prices are set jointly in the two chain managed hotels. As we discuss in section 5, there is some evidence consistent joint pricing across chain managed properties in the data. This effect is dominated by the information asymmetry and uncertainty aversion story in the overall data.

incorporate multiple priors into axiomatic decision making is maximin utility. The uncertainty averse decision maker evaluates each action by its minimum expected utility under all possible priors and selects the action that maximizes the minimum expected utility. They demonstrate the effects on price of an increase in uncertainty. In our context, each revenue manager is uncertain about the level of the demand intercept. They have multiple priors about the probability distribution of the intercept over a given range, the bounds of which are a function of the precision of their information. Expected utility for the property is minimized by a malevolent nature under the prior of the least favorable demand, which is the prior which attaches probability 1 to the intercept being equal to the lower bound of the range.

There is information asymmetry in the last period. The relatively uninformed party (the franchised hotel) has uncertainty about the level of the demand intercept and also about the increase in precision of the rival's information. He hence adopts a pricing rule that is robust to both sources of uncertainty. From the point of view of the franchised property, the least favorable outcome is that the chain managed property has the same information set as the franchised property, that is, the chain's information did not increase in precision between the first and last periods. The informed party (the chain managed hotel) has knowledge of the bounds of his own set of priors, and those representing the information set of the uniformed party (the franchise). We derive the two-stage subgame perfect Nash equilibrium when both revenue managers use robust decision rules.

To our knowledge, this paper is one of the first to examine the empirical consequences of robust decision making as a response to uncertainty aversion in a specific industry setting. Recent theory papers develop the implications of uncertainty for pricing. For example, Tapking (2004) examines the equilibrium outcome of a Cournot game when firms have private information about their marginal costs. Each firm sets prices to maximize Choquet utility, which places weight on the worst case outcome where the weight is a function of uncertainty aversion. He finds that the more uncertainty averse they are, the less likely are firms to share cost information.

Perakis and Sood (2006) construct a multi-period pricing model for an oligopoly when each competitor has fixed inventory, as in our case. For a general demand function with uncertainty, sellers set prices using a robust policy which maximizes the objective function under the most adverse instances of demand within the set of possible demands. They use a framework of variational inequalities to establish existence and uniqueness of equilibrium pricing policies, develop an algorithm for computing robust equilibrium policies, and illustrate the results with numerical simulations. Some of their findings deliver insights that are similar to the predictions of our simple linear demand specification with uncertainty about the intercept term. For example, they note that in a two player game, when one player adopts a robust pricing policy and one does not – which corresponds to the latter player having no uncertainty about demand – the uninformed player sets lower prices and sells more units. The informed player also sets lower prices, and both firms receive lower payoffs.

Vives (1984) and Gal-Or (1985) demonstrate that in settings where firms have private information about uncertain demand, information sharing is an equilibrium strategy when products are substitutes and firms compete in prices, but that information is not shared when firms compete in quantities. This insight applies in our model where firms compete in prices. If the chain property knew the extent to which its information about demand would become more precise, it would choose to reveal this to the franchise leading to higher prices for both properties in the last period. We assume this information is only available to the chain after the first period, when it can observe the fraction of rooms booked at both hotels during the first period.

We find it interesting, and consistent with the set up of our model, that some hotel brands offer revenue management services to its franchised properties for a fee.[5] Our model suggests that when franchised hotels have more precise information about demand, both properties set higher prices and both are better off. The fact that the brand charges a positive amount to franchised hotels for these services is the outcome of a bargaining game over how these gains are divided between headquarters and each franchised property.

Section 2 describes the data used in the paper. Section 3 presents the empirical investigation of price trends and organizational form to motivate the model. Section 4 presents the model of the pricing game under asymmetric information and uncertainty aversion. Section 5 presents the triple differences empirical results to add support to the model and discusses implications of the findings. Section 6 concludes.

2 Hotel property-level data

This paper analyzes property-level data from two different sources. The first data set contains information about non-varying hotel characteristics and includes all the US properties for six hotel brands: Four Points, Hyatt, Marriott, Radisson, Sheraton, and The Westin.[6] The data include the number of guest rooms, the square footage of meeting space, whether or not the hotel offers

[5] For example, Marriott offers a package called "Revenue Management for Hire" to all its franchised properties.

[6] This data was purchased from the industry research firm Smith Travel Research (STR).

conference facilities, has a convention center, is close to a golf course and whether it has a spa. The longitude and latitude of the property are given in the data which also assign each hotel to two different location groupings: a market and a tract. There are 136 markets in the US and 359 tracts. Last, the data also reveal whether the property is chain managed or franchised. Table 1 summarizes the hotels in the data by brand.[7] A hotel is classified as having vacation facilities if it has either a golf course and/or a spa. It is classified as having the ability to host conferences if it has conference facilities and/or a convention center.

The second data set contains price data gathered from hotel websites over three different time periods in 2008 and 2009. In each case, we chose a date of stay some time in the future and downloaded the set of prices offered on each hotel website for the relevant date of stay on each day leading up to the date of stay itself. The first data set contains the prices offered for each of the 31 days leading up to June 30th, 2008. The second data set contains the prices offered for each of the 14 days leading up to July 20th, 2008. The third data set contains the prices offered on each of the 41 days leading up to March 4, 2009. We downloaded the data from each hotel's proprietary website because each brand in the data offers a best rate guarantee so that the minimum price posted on the website matches the prices offered for the specific hotel on third party sites. For most hotels, on most days, a range of prices was offered on each day corresponding to different room types.

Table 2 summarizes the price data for each data set on the first and last day of each time period, by brand, and by organizational form. In general, the average of the minimum prices offered for a brand-organizational form is lower on the last day of the data than on the first day. The average maximum price also tends to be lower on the last day than on the first day. The average number of prices offered on the last day is lower for some brands-organizational forms and higher in others in the first and second data sets, and lower on the last day in the third data set. There is no systematic relationship between organizational form and the standard deviation of the minimum or maximum prices offered within a brand.

The change in the number of observations between the first and last day for each brand-organizational form reflects, for the most part, the fraction of hotels which are fully booked by the date of stay. The Radisson hotel in the first and second data sets reveals a relatively large proportion of fully booked hotels, but relatively few other hotels from the other brands display no available rooms on the day of the date of stay.[8] In some cases, the number of observations increases

[7] Table 1 has three panels corresponding to the hotels present in each price data download. The summary statistics are very similar across the different dates of stay.

[8] For this reason, as well as a lack of detailed data about property occupancy rates, we are reluctant to include capacity considerations in our model. We effectively assume that each hotel has a large number of unsold rooms in

between the first and the last day for a brand-organizational form combination. This is most likely because either the hotel's website or our webcrawler program was not functioning properly on the first day.

Table 3 presents pairwise correlations between prices and non-varying hotel characteristics in each data set. The first column of each panel reveals that chain managed properties tend to set higher minimum prices, higher maximum prices, and offer a larger number of different prices. They also tend to be larger, in terms of guest rooms and meeting space square footage, to be farther away from corporate headquarters, and to be more likely to have vacation and conference facilities. The remaining columns reveal that prices also tend to be positively correlated with size and the presence of hotel amenities. A higher minimum price is positively correlated with a higher maximum price but is generally negatively correlated with the number of prices offered. Size, distance to corporate headquarters, and the presence of amenities are positively correlated.

Much of the analysis in the paper will focus on the lowest price offered by each hotel on each day. In our analysis, to date, we have chosen not to focus on the role played by capacity constraints in these markets, either at the hotel level or at different price points within a hotel. Our data does not reveal the dates on which rooms are booked, the fraction of rooms offered at each posted price on any one day, or property-level occupancy rates on the dates of stay. Prescott (1975) considers price dispersion in hotel room rates in a setting of uncertain demand when hotels commit to offering a given number of units at a low price and a given number at a high price. Eden (1990) and Dana (1999) show that price dispersion can be an equilibrium outcome even when sellers can change their prices and under differing amounts of seller market power. Escobari and Gan (2007) find evidence supporting some of the predictions of these models in the context of the airline industry.

While our data reveals price dispersion within hotels, since most offer a range of prices on any one day corresponding to room types, we have focused on the dynamics of the lowest price offered by each hotel. Anecdotal evidence suggests that hotels are able to vary the allocation of units priced at the lowest rate as the date of stay approaches and that the lowest rate offered is the most frequently booked. At the time of our analysis, the vast majority of hotels had rooms available on the date of stay for the date of stay suggesting that very few faced binding capacity constraints. It does not appear to be the case that chain managed hotels set higher relative prices closer to the date of stay either because the lower priced rooms in these hotels were all booked, or because market power for chain hotels increased as franchised hotels sold out.[9]

each period relative to market demand.

[9]This fact suggests that all hotels priced too high in the run up to the date of stay. The presence of capacity

As mentioned in the introduction, several papers examine the relationship between organizational form and the average price paid by guests as reflected in hotel revenues. Vroom and Gimeno (2007) report that, on average, prices at franchised hotels are lower than at chain managed hotels in their data set of Texan hotels. Kosova et al. (2007) report a similar finding in their proprietary US firm data. Both these papers discuss the challenges of attributing causality to this relationship and proceed by examining the potential endogeneity of organizational form choice. The price data we have do not reveal average prices paid since the distribution of booking times is unobserved. We have chosen to focus on changes in price levels to avoid the most pressing endogeneity concerns.

As motivation for the analysis of relative price trends, we regress the level of the lowest price offered at each hotel on a variable indicating whether the property is franchised and brand fixed effects on the first and last day of each data set. These regressions are reported in Table 4. In each of the six regressions, the lowest prices offered by franchised properties are significantly lower than the lowest prices posted by chain managed hotels, consistent with the findings in Vroom and Gimeno (2007) and Kosova et al. (2007). In the first and second data set the magnitude of the price difference is larger on the last day of the data than on the first day. In the third data set, the difference in price between franchised and chain managed hotels is smaller on the last day of the data.

Figure 1 plots the average price changes in the run up to the date of stay for each data set. Each specification includes property fixed effects, and the omitted day is the first date in the data set in each case. In the first data set (where the data was missing for two days over the duration), prices fall in the run up to the date of stay but are fairly volatile, including a large increase on the day before the date of stay. In the second data set, prices increase over time on average. In the third data set, prices fall for the first two weeks then show a slight tendency to increase towards the date of stay.

Figures 2, 3, and 4 decompose the different average price trends into the price trends for chain managed hotels and franchised hotels in each data set. In each data set, the price levels in franchised hotels fall by a greater amount or rise by a smaller amount since the start of the data set than prices offered by chain managed hotels. The magnitude of the difference between the chain managed and franchised hotel price change since the start of the data set tends to grow as the date of stay approaches. The three data series of the difference between franchised and chain managed prices relative to the start of each data set are plotted on the same axes in Figure 5. Franchised hotels

constraints could play a role in the pricing game even though not binding, since we know chain properties are typically larger than franchised properties. Exploring the role of capacity is work in progress.

exhibit a larger negative price trend than do chain managed hotels. This pattern is the subject of more detailed investigation in the remainder of the paper.

3 Price Trends and Organizational Form

We assume that demand is independent of organizational form and focus on price trends so that unobservable hotel characteristics correlated with both price level and organizational form can be conditioned out of the analysis. As mentioned in the introduction, we use a difference-in-differences approach to identify the association between organizational from and relative price trend. We test the significance of the estimate of the difference between the price trend – that is, the difference in price level over time – for franchised and chain managed hotels. In sum, we investigate whether the relative price trend for franchised hotels is significantly different from zero.

Benchmark specification

The benchmark specification that we take to the data is:

$$\ln(p_{i,t}) = \alpha + \beta_i + \gamma d_t + \varphi d_t f_i + \varepsilon_{i,t} \tag{1}$$

where $p_{i,t}$ is the lowest price listed on hotel i's website on day t, α is a constant term, β_i is a property fixed effect for property i, d_t is the number of days that have passed since the start of the data set, and f_i is an indicator variable equal to 1 if property i is franchised and equal to 0 if property i is chain managed. The difference-in-differences estimate is given by the average over all days $t+1$ and t in the data of:

$$\widehat{\varphi} = \left(\overline{p}_{f,t+1} - \overline{p}_{f,t}\right) - \left(\overline{p}_{c,t+1} - \overline{p}_{c,t}\right)$$

where $\overline{p}_{f,t}$ is the average of franchised hotels' prices on day t relative to each hotel's average price, and $\overline{p}_{c,t}$ is the equivalent for all chain managed hotels.

The results from these regressions are given in Table 5. In each case, the dependent variable has been multiplied by 100 to simplify presentation of the coefficient and standard error estimates.[10] Standard errors are clustered at the property-week level to allow for serial correlation in the property-level errors that might also be related to demand shocks which persist over time. The

[10] When the dependent variable is not amplified in this way, so the natural log of lowest price is used, the coefficient and standard error estimates are very small. The coefficients represent the estimated effect on prices of one day passing.

first three columns present the results for the log of the minimum price. In each case, the estimate of φ is negative and significant. Franchised hotels have a negative relative price trend.

Since the independent variables have been multiplied by 100, the estimated coefficients measure the percentage change in the minimum price offered resulting from a unit increase in the independent variable. The franchised hotel differs from the chain managed hotel on each day by a percentage equal to φ multiplied by the number of days that have already passed. In the first data set, each day that passes is associated with a further 0.14% gap between chain managed and franchised hotels. At the end of the data set, after 31 days have passed, franchised hotel prices have fallen more than chain managed hotel prices by an average of 4%. In the second data set, each day is associated with a 0.12% relative price decline for franchised hotels so that after the 14 days of the data sample, franchised hotel prices are an average of 1.7% lower than chain managed hotel prices. In the third data set, each day is associated with a 0.04% relative price decline, corresponding to price level that is 1.6% lower at the end of the 41 day data sample.

The next six columns of Table 5 replace the dependent variable with the natural log of the maximum price multiplied by 100 in each of the three data sets and the natural log of the number of prices offered multiplied by 100 in each data set. For chain hotels the maximum price and the number of prices both fall over time. There is no significant difference between the rate of decline in maximum price listed for franchised hotels and chain hotels. In the third data set, the franchised hotels offer fewer different prices over time.

The final three columns of Table 5 examine whether organizational form is associated with the probability of making a change in the lowest price offered on any one day. A conditional logit specification finds that in the first and third data sets, there is no significant difference in the probability of a price change on any one day for franchised and chain managed hotels. Neither does the relative likelihood that a franchise changes its price differ over time. In the second data set, franchises are less likely to make a price change on any one day than are chain managed hotels. This difference in the relative probability of making a price change falls as the date of stay approaches.

The negative relative price trend in minimum offered price for franchised hotels is present in each of the three different time periods and, to our knowledge, has not been previously identified in the literature. Franchised hotels reduce prices at a faster rate in the run up to the date of stay. Organizational form is shown to be associated with differing revenue management practices in these US hotels.

Controlling for observable hotel characteristics

Our approach so far has allowed us to control for the presence of hotel characteristics that affect both whether a hotel is franchised and its price level. We acknowledge, though, that the choice of organizational form and the price trend may both be associated with other hotel characteristics. For example, Kalnins (2006) points out that around half of hotel bookings in the US are made through corporate accounts or for conferences and we might expect pricing trends to reflect cross-hotel variation in these types of reservations. The following specification was estimated to explore, and control for the roles played by the number of guest rooms, the total meeting space, vacation and conference facilities, and distance to headquarters, on price trend:

$$\ln(p_{i,t}) = \alpha + \beta_i + \gamma d_t + \varphi d_t f_i + \phi d_t x_i + \varepsilon_{i,t} \tag{2}$$

where x_i is one of the five observable hotel characteristics. The results of these estimations are given in Panel A of Table 6. The estimated coefficient, φ, remains negative and significant in each specification. This suggests that while observable hotel characteristics are correlated with organizational form, they are not also correlated with price trend in a way that can explain the price trends identified in Table 5. We also note that the magnitude of the coefficient estimates are similar within each data set. This offers some indirect evidence that the relationship between organizational form and price trend is not driven by unobservable property characteristics that are also correlated with the observable characteristics included here.

Our goal is to explain why decision-making about price trend differs between chain managed and franchised hotels. To try and shed some light on this, we ask whether the difference in relative price trend is particularly strong for franchised hotels which share other characteristics. To do this, we estimate the following triple differences specification:

$$\ln(p_{i,t}) = \alpha + \beta_i + \gamma d_t + \varphi d_t f_i + \phi d_t x_i + \rho d_t f_i x_i + \varepsilon_{i,t} \tag{3}$$

where ρ is the coefficient estimate on the three way interaction variable between days passed, the franchise indicator variable, and another observable hotel characteristic. These results are given in Panel B of Table 6. There is little consistent evidence across the data sets that property level characteristics affect the magnitude of the relative price trend difference. In the first data set, franchised hotels with a large meeting space reduce prices at a slower rate than franchised hotels with less meeting space. In the third data set, franchised hotels with conference facilities reduce prices less than those without conference facilities.

Controlling for observable market-level characteristics

The hotels in the data compete with each other across many separate geographic markets. It is possible that HQ's choice of organizational form is related to the nature of the competition in a market which also has an independent effect on revenue management practices. We re-estimate equations (2) and (3) including market level variables for each of the 136 markets in which the hotels are located in the place of x_i. The variables used are the number of properties of all brands in the market, the market-level HHI of guest rooms, calculated as the sum of squared property-level shares of market rooms, and the HHI normalized for the number of properties in the market.[11]

In Panel A of Table 7, we see that the negative coefficient estimate for φ remains when including variables to control for the separate effects of market-level variables on property price trends. We also note that the market-level variables have a separate effect on price trend. In particular, hotels in larger markets – those with a larger number of properties – tend to reduce prices faster as the date of stay approaches. This coefficient estimate is significant in the first and third data sets. Hotel properties in more concentrated markets tend to cut prices less fast as the date of stay approaches. The room-based HHI is positively and significantly associated with price trend in the first and third data sets, and the normalized room-based HHI is positive and significant in the second data set.

We now turn to whether variation in market structure affects the magnitude of the relative price trend difference between chain managed and franchised properties. Including three way interactions between days passed, whether a property is franchised, and market characteristics gives the results shown in Panel B of Table 7. In both the first and third data set, we see that the negative relative price difference between chain managed and franchised hotel is present only for franchised hotels in large markets. Once the three way interaction of days passed, franchised, and market size is included, the coefficient estimate on the interaction of franchise and days passed becomes insignificant in the first data set and positive and significant in the third data set. When three way interaction terms are included to measure the role of market concentration, we see that franchised hotels in less concentrated markets reduce prices by more than franchised hotels in concentrated markets. Taken together, these results suggest that market structure plays a role in determining the magnitude of the negative relative price trend shown by franchised hotels. We explore this further

[11] These market-level variables were constructed using data on the six brands used in the study and do not include data on the brands not used in the study. The next version of the paper will include more comprehensive market data.

in section 5.

4 The Model: Two Hotel Game

The environment and information structure

There are two hotel properties in the market: hotel 1 is a franchised property and hotel 2 is managed by the chain. In this duopoly game, in each of two periods $t = \{T, 0\}$, each hotel faces a symmetric linear demand function which gives the probability that an empty hotel room will be booked on day t as a function of each hotel's price and a market level intercept term. This function is given by:

$$s_{i,t} = \widetilde{a}_{i,t} - bp_{i,t} + cp_{j,t} \tag{4}$$

for hotel i, $i = \{1, 2\}$. The marginal cost of a guest's stay is incurred on the date of stay and is independent of the date of booking. This cost is constant across hotels and normalized to zero hence profit maximization is equivalent to revenue maximization in this setting.

Each hotel is uncertain about the value of $\widetilde{a}_{i,t}$. In the first period, $t = T$, this uncertainty is symmetric. The uncertainty is represented by a set of possible distributions of $\widetilde{a}$. We assume that each hotel knows that $\widetilde{a}_{i,T} \in [a, a']$ for $i = \{1, 2\}$. In the second period, the chain hotel has access to better quality information about market demand since it can observe booking rates at both hotels. This allows it to narrow its precision about the set of possible distributions for $\widetilde{a}$, and in particular, the range of possible values of $\widetilde{a}$. For the chain hotel then, $\widetilde{a}_{2,0} \in [\overline{a}, \overline{a}']$ where $a < \overline{a}$ and $\overline{a}' < a'$. For the franchise hotel, we assume there is no increase in the precision of their demand estimate so $\widetilde{a}_{1,0} \in [a, a']$ in both periods.[12]

In the classic case of revenue maximization, each risk neutral hotel sets price in each period to maximize expected revenue given the presence of the other hotel for a given prior $\widehat{F}(\widetilde{a})$, where the expected value is equal to $E(\widetilde{a})$ in both periods for both hotels. The price in the first period will differ from the price in the last period due to the change in the opportunity cost of booking each room, which falls from a positive value to zero between periods T and 0. The symmetry of the game tells us that the price change over time will be equal for each hotel so that there is no predicted difference in price trend between the franchised and chain managed hotel under asymmetric information when each sets price so as to maximized expected revenue.

[12] If the value of $\overline{a}$ were known in the first period by the chain, it would find it worthwhile to price so as to reveal this information (or reveal it directly) with the effect of raising the franchise's price in the second period. Prices are strategic complements in this setting. We assume $\overline{a}$ is unknown by the chain until the start of the last period.

In the robust version, we assume that each hotel is uncertainty averse. One way to model decision making with uncertainty aversion is a maximin utility approach over multiple priors where the set of priors is all the possible distributions for a over the range $[a, a']$. The decision maker evaluates each possible action by its minimum expected utility across all possible actions taken by an adversarial nature. He then selects the action that maximizes the minimum expected utility. The pricing policy is an equilibrium strategy of a zero sum game between each hotel and an adversarial nature.

In this two-player application, there is an additional source of uncertainty for the franchised property in the last period. The franchise understands that the chain's information is more precise, but does not know the value of $\overline{a}$ or $\overline{a}'$. The franchise uses a minimax approach where the strategy space of the adversarial nature also includes the choice of $\overline{a}$ as well as a, within a neighborhood of the true model where the neighborhood is bounded by $\overline{a} \in [a, a']$. Since the franchise is worse off when the chain prices low, utility is minimized for the franchise when nature chooses $\overline{a}$ equal to its lowest value in the neighborhood. That is, as if the chain does not increase its precision and acts as if $\overline{a} = a$. The chain hotel, in contrast, knows the value of $\overline{a}$ and also knows that the franchise is acting as if $\overline{a} = a$.

In sum, in each period, hotel i chooses $p_{i,t}$ to solve:

$$\arg \max_{p_{i,t} \in R} \min_{\widetilde{a}_{i,t} \in F_{i,t}} (V_{i,t}) = s_{i,t} p_{i,t} + (1 - s_{i,t}) V_{i,t+1}$$

where

$$s_{i,t} = \widetilde{a}_{i,t} - b p_{i,t} + c p_{j,t}$$

and $F_{1,T} = F_{2,T} = F_{1,0} \in \phi(a, a')$ is the set of multiple priors about the distribution of $\widetilde{a}$ under the initial uncertainty, and $F_{2,0} \in \overline{\phi}(\overline{a}, \overline{a}')$ is the set of priors held by the chain in the last period with better quality information. That is, for the franchise, the equilibrium pricing path $(p_{1,T}, p_{1,0})$ is the solution to:

$$\begin{aligned} \max_{p_{1,T}} V_{1,T} &= \left(a - b p_{1,T} + c p_{2,T}\right) p_{1,T} + (1 - \left(a - b p_{1,T} + c p_{2,T}\right)) V_{1,0} \\ \max_{p_{1,0}} V_{1,0} &= \left(a - b p_{1,0} + c \widehat{p}_{2,0}\right) p_{1,0} \end{aligned}$$

since the value of the hotel room goes to zero at the end of the last period (a non-durable good). We note that the franchise does not know the chain's information set in $t = 0$, so it uses a decision rule that is robust to the uncertainty about the value of $\overline{a}$.

For the chain property, the equilibrium pricing path $(p_{2,T}, p_{2,0})$ is the solution to:

$$\begin{aligned}
\max_{p_{2,T}} V_{2,T} &= \left(a - bp_{2,T} + cp_{1,T}\right) p_{2,T} + (1 - \left(a - bp_{2,T} + cp_{1,T}\right))V_{2,0} \\
\max_{p_{2,0}} V_{2,0} &= \left(\overline{a} - bp_{2,0} + cp_{1,0}\right) p_{2,0}
\end{aligned}$$

where $p_{1,0}$ is the actual price set by the franchise since the chain has complete information about the franchise's equilibrium strategy. We present the subgame perfect equilibrium to this game below. In equilibrium, the franchised property cuts price by more in the second period.

In the appendix, we construct a three hotel model where there are two chain hotels for which prices are set jointly, taking demand externalities into account. In the absence of robust pricing, joint pricing across chain hotels leads to chain properties reducing price by a greater amount. In the second version of the model presented in the appendix, both robust pricing as a response to uncertainty aversion together with joint pricing by chain properties are included. We illustrate when the information asymmetry effect dominates the multiproduct pricing effect, meaning that franchises reduce prices faster even when competing with several chain managed properties for which prices are set jointly.

Price levels in the final period, on the date of stay, $t = 0$

The value function for the franchised property on the date of stay reflects the non-durable nature of the hotel room for a given night. If it remains unsold today its value is 0. The value function is:

$$V_{1,0} = s_1 p_1 + (1 - s_1)0$$

Differentiating with respect to p_1 gives:

$$\begin{aligned}
\frac{dV}{dp_1} &= s_1 + \frac{ds}{dp_1} p_1 \\
&= a - bp_1 + cp_2 - bp_1
\end{aligned}$$

We note that the actual p_2 is unknown to the franchise property, moreover the information available to the chain when choosing p_2 is unobserved by the franchise. The franchise's estimate of the chain's decision-making rule is that the chain is employing the same demand function as the franchise.[13]

[13] This approach is similar to Ponssard (1976), where all competitors know who acquires information, but the content or outcome of the information acquisition is known only to the competitor who acquires it.

We denote the franchise's worst case scenario for the price the chain will set as $\widehat{p_2}$. Then the franchise's revenue maximizing price in the last period, using the maxmin decision rule, is:

$$p_1 = \frac{a + c\widehat{p_2}}{2b}$$

Since $\widehat{p_2}$ is based on the same pessimistic view of demand as the franchises information set, we note that due to symmetry:

$$\widehat{p_2} = \frac{a + cp_1}{2b}$$

Substituting $\widehat{p_2}$ into the equation for p_1 gives:

$$\begin{aligned} p_1 &= \frac{a + c\widehat{p_2}}{2b} = \frac{a + cp_1}{2b} \\ p_1 &= \frac{a}{2b - c} \end{aligned} \tag{5}$$

For the chain property, the value function is given by:

$$V_C = s_2 p_2 + (1 - s_2)0$$

where the probability function employed as the worst state of the world by the chain, s_2, includes the intercept $\overline{a}$ rather than a, since the chain has greater precision about the true nature of demand in this period. Differentiating with respect to the chain's price gives:

$$\begin{aligned} \frac{dV}{dp_2} &= s_2 + \frac{ds}{dp_2} p_2 \\ &= \overline{a} - bp_2 + cp_1 - bp_2 \end{aligned}$$

We note that the chain's information set includes the fact that the franchise is pricing according to its more pessimistic view of the world, hence the chain can anticipate the franchise's price perfectly. Rearranging the first order condition for p_2 and substituting in for p_1 gives:

$$p_2 = \frac{2\overline{a}b - c\left(\overline{a} - a\right)}{2b\left(2b - c\right)} \tag{6}$$

We note here that the price set by the chain property is higher than the price set by the franchise.[14] Also, however, the second term in the numerator of p_2 reflects the fact that prices are strategic

[14] The difference between the chain and franchise price is $\frac{(2b-c)(\overline{a}-a)}{2b(b-c)}$. This is positive since $\overline{a}$ is assumed to be greater than a, and b greater than c.

complements. The chain knows that the franchise will set a low price and chooses to reduce its price below what would be optimal if both properties were competing under symmetric information of demand where both employed the demand function including $\overline{a}$ in their decision rule.

Price levels in the first period, the day before the date of stay, $t = T$

In the earlier period, the problem is entirely symmetric since both properties have the same information structure. The value function for each property is:

$$V_{i,T} = s_i p_i + (1 - s_i) EV_{i,0}$$

Where $EV_{i,0}$ is the expected value of the property in the last period. The second term in this value function is the opportunity cost of selling the room today. The estimate of this value is equal for each property. Although it is common knowledge that the chain hotel will have more precise information in the last period, neither hotel is able to anticipate the extent to which precision will increase.

Differentiating with respect to price and rearranging the first order condition for each hotel gives:

$$p_{1,T} = p_{2,T} = \frac{a}{2b - c} + \frac{bEV_0}{2b - c} \tag{7}$$

A comparison of price trends

Price falls over time at the franchise because the only change between T and 0 is the opportunity cost of no sale in each period. This cost falls from a positive value to zero. Hence the price change at the franchise is the change in the opportunity cost between the two periods. Comparing equations (5) and (7) tells us that the change in price at the franchised hotel between $t = T$ and $t = 0$ is:

$$\begin{aligned} \Delta F &= \frac{a}{2b - c} + \frac{bEV_0}{2b - c} - \frac{a}{2b - c} \\ \Delta F &= \frac{bEV_0}{2b - c} \end{aligned} \tag{8}$$

There are two effects at work in the chain property. Price will fall due to the change in opportunity cost of no sale from period T to period 0, however, increased precision about the nature of demand in the later period leads the chain to increase price (even though it knows the franchise will continue to price based on the old information). Equations (6) and (7) tell us that the net effect on the change in price at the chain hotel is:

$$\Delta C = \frac{a}{2b-c} + \frac{bEV_0}{2b-c} - \left(\frac{2\overline{a}b - c\left(\overline{a}-a\right)}{2b\left(2b-c\right)}\right) \tag{9}$$

The difference between the price changes at each property tells us whether the franchise or the chain reduces price by a greater amount. The price cut at the franchise is greater than at the chain property iff $\Delta F > \Delta C$:

$$\begin{aligned}
\frac{bEV_0}{2b-c} &> \frac{a}{2b-c} + \frac{bEV_0}{2b-c} - \left(\frac{2\overline{a}b - c\left(\overline{a}-a\right)}{2b\left(2b-c\right)}\right) \\
\left(\frac{2\overline{a}b - c\left(\overline{a}-a\right)}{2b\left(2b-c\right)}\right) &> \frac{a}{2b-c} \\
(2b-c)(\overline{a}-a) &> 0
\end{aligned}$$

Since $b > c$ by assumption, this inequality demonstrates that the franchised hotel will reduce price by a greater amount than the chain managed property if there is any relative increase in the uncertainty averse chain manager's precision about demand in the second period, that is if $\overline{a} > a$.[15]

5 Triple Differences Analysis based on Variation in Market Structure

In section 3, we saw that variation in market structure across different geographic markets affected the magnitude of the negative relative price trend for franchised hotels. We now ask whether the differences in relative price trend across markets seen in the data are consistent with the mechanisms at work in the model. We proceed with caution here given the simple structure of the theory model and the fact that demand-related parameters in the model cannot be assumed constant across markets. Nonetheless, we report two sets of findings which are broadly consistent with the model's predictions.

First, we recall that joint pricing across chain managed hotels in a market predicts that chain managed hotels reduce prices faster than franchised hotels, as shown in the appendix. This is a result of the strategic complementarity of prices in this game. The larger the proportion of same-brand properties that are chain managed, the larger the proportion of hotels over which prices are jointly

[15] This prediction is robust to positive or negative demand shocks in the final period that shift the lower bounds of each hotel's priors symmetrically. Hence, it is more general than a result that suggests the chain is learning about non-varying demand over time.

set. We infer from this that in markets with a large share of same-brand chain managed properties, the relative price trend for franchised properties will be positive. A triple difference estimation was carried out including the three way interaction between days passed, the franchise indicator, and the share of same-brand properties that are chain managed. The estimated coefficient on this triple interaction term is positive and significant in the second and third data sets. The coefficients remain positive and mostly significant when controls for market size and market concentration are included, although they become insignificant when controlling for the number of same-brand properties in the market. We interpret this as some evidence of joint pricing across horizontally integrated properties in a market.

Second, we turn to a specification that offers evidence consistent with the presence of asymmetric information and uncertainty aversion. We recall that the hypothesized source of the information asymmetry between chain managed and franchised hotels is that the chain has access, through the booking system, to more detailed information about reservation rates in all brand properties whereas a franchise sees only the fraction of their own rooms that have been reserved. We infer that the larger the number of franchised hotels contributing information to the booking system, the larger the information asymmetry. For example, if there is one chain managed property and one franchised property of the same brand in the market, the chain hotel observes data from two hotels and the franchised hotel observes data from one. If another franchised hotel is added to the market, and begins to contribute information to the booking system, the chain managed property now observes data from three hotels and each franchise observes data from only one, further increasing the chain managed property's relative precision in their market demand estimate.

We carry out a triple difference specification including the three way interaction of days passed, the franchise indicator, and the number of franchised hotels of the same brand in the market. We run specifications that control for the size of the brand in the market, the size of the market, and the market concentration. These results are given in Panel B of Table 8. In the second data set, the three way interactions are not significant but franchised hotels, on average, continue to have a negative relative price trend. In the first and third data sets, we see that in markets where there are a larger number of same-brand franchised hotels, franchised hotels have a significantly larger negative price trend. We interpret this as consistent with the predictions of the model.

6 Conclusion

Much of the work in industrial organization on the consequences of vertical integration for outcomes in the downstream market is motivated by the conjecture that the vertical integration of a downstream and upstream activity unifies control rights over the decisions made in each activity (Gibbons, 2005). Coordination of the two activities is made easier – which is the theory tested, for example, in Forbes and Lederman – and joint profits can be maximized with various implications for welfare. Riordan (2005) describes the implications of vertical integration for market power and competitiveness.

In this paper we note that variation in firm boundaries may also affect the information structure of the market. In particular, whether or not a downstream activity is integrated into headquarters may affect their information about market demand. Anecdotal evidence suggests that this is the case in the hotel industry since integrated properties have more information about market demand and, arguably, more resources to process that information. In this industry, a mix of organizational forms exists within geographic markets, creating an asymmetry in information about market demand. We explore the implications of this for price - levels and trends - in a simple theory model, and examine the relative price trends empirically.

The franchised hotel properties in our data exhibit a significant negative relative price trend for three different time periods in US brand affiliated hotels. These non-integrated firms cut prices by more or raise prices by less on average than properties that are integrated into the firm. This finding remains when the separate effects on price trend of other observable characteristics are included. Moreover, there is evidence from across markets that this effect is particularly strong when a larger number of franchised hotels of a given brand exist in a market.

Empirical work demonstrating that organizational form has any impact on market outcomes is limited, mainly due to endogeneity problems. Lafontaine and Slade (2007) provide a comprehensive survey of theory and evidence relating integration decisions to firm outcomes. Relatively few papers explore the role of organizational form as an independent variable in explaining differences in performance.[16]

We develop a simple two-player, two-period game with asymmetric information about market demand and uncertainty aversion which generates predictions for relative price trends that are

[16] Several papers remark on the gap in empirical evidence on this topic, for example, Mullainathan and Scharfstein (2001) and Hubbard (2008). Papers that do investigate this relationship in other industries include Mullainathan and Scharfstein's paper and Guedj (2006) on the pharmaceutical industry, Novak and Stern (2007) in automobiles, Gil (2007) in the movie industry, and Forbes and Lederman (2009) in airlines.

consistent with the empirical findings. The relatively uninformed player - the franchised hotel in our context - has a negative relative price trend. The model draws on the literature on pricing with incomplete information and robust decision making under uncertainty.

Other implications of vertical integration related to joint control, for example, joint pricing across vertically integrated properties within a market, cannot explain the empirical findings. We find some evidence of joint pricing in the data, in that the negative relative price trend for franchises is decreasing in the share of market properties that are chain managed, but this effect is outweighed on average by the negative price trend for franchised properties.

As noted in Vives (1984), variation in the information structure has implications for welfare. In our model, the presence of a relatively uninformed player in the market means that all players price lower. Hence, franchised properties generate positive externalities for consumer surplus in the market, reducing profits for all properties. Vroom and Gimeno (2007) suggest that franchised properties can cause negative reputation externalities for a brand by their inability to commit to maintaining high price levels. In this paper, we identify another channel through which franchised hotels generate negative spillovers for the brand with which they are affiliated by increasing price competition.

Appendix

Three hotel game with no uncertainty aversion

We examine the implications for price trends of horizontal integration of vertically integrated properties within a market when there is no uncertainty. In a given market there are three properties that are symmetrically differentiated. Property 1 is a franchise and properties 2 and 3 are horizontally integrated in a chain. The price levels and trends differ by organizational form because the chain integrates demand spillovers when setting price in each of its properties, and this also changes the nature of game in each period for all properties.

There are two periods, the last of which is the day of the date of stay labelled $t = 0$. The prior day is period T. In period $t \in (T, 0)$, the probability that an empty room in hotel i is reserved is given by the linear function:

$$s_{i,t} = a - bp_{i,t} + \sum_{j \neq i} cp_{j,t} \tag{10}$$

The parameter b measures the own price elasticity and the parameter c measures the cross price elasticity with regard to the prices set by the other two properties in the market on day t. For simplicity, marginal costs are identical in each hotel and normalized to zero.

Price levels in the final period, on the date of stay, $t = 0$

Each decision maker chooses prices to maximize revenues. For the franchise, revenues are the price multiplied by the probability of sale in the single property. For the chain, the objective is to maximize the joint revenues of the two chain properties, taking the demand spillovers between these properties into account. For the franchise:

$$\begin{aligned} V_F &= s_1 p_1 + (1 - s_1)0 \\ \frac{dV}{dp_1} &= s_1 + \frac{ds}{dp_1} p_1 \\ &= a - bp_1 + cp_2 + cp_3 - bp_1 \end{aligned}$$

The first order condition gives:

$$\begin{aligned} 2bp_1 &= a + c\left(p_2 + p_3\right) \\ p_1 &= \frac{a + c\left(p_2 + p_3\right)}{2b} \\ p_1 &= \frac{a + 2cp_2}{2b} \end{aligned} \tag{11}$$

where the last step follows since symmetry of the chain properties means they will set the same price in each property.

For the chain, the objective function includes the revenues of both properties:

$$\begin{aligned} V_C &= s_2 p_2 + s_3 p_3 + (1 - s_2)0 + (1 - s_3)0 \\ \frac{dV}{dp_2} &= s_2 + \frac{ds_2}{dp_2} p_2 + \frac{ds_3}{dp_2} p_3 \\ &= a - bp_2 + cp_1 + cp_3 - bp_2 + cp_3 \\ &= a - 2bp_2 + 2cp_3 + cp_1 \end{aligned}$$

The first order condition with respect to the choice of p_2 is:

$$\begin{aligned} 2bp_2 &= a + 2cp_3 + cp_1 \\ p_2 &= \frac{a + c\left(p_1 + 2p_3\right)}{2b} \end{aligned}$$

Since the price for the other chain property, property 3, is:

$$p_3 = \frac{a + c\left(p_1 + 2p_2\right)}{2b}$$

the price in each chain hotel can be simplified to:

$$\begin{aligned} p_2 &= \frac{a}{2b} + \frac{c}{2b} p_1 + \frac{c}{b} p_2 \\ p_2\left(1 - \frac{c}{b}\right) &= \frac{a}{2b} + \frac{c}{2b} p_1 \\ p_2 &= p_3 = \frac{a + cp_1}{2\left(b - c\right)} \end{aligned} \tag{12}$$

Solving equations (11) and (12) jointly for p_1 and p_2 gives:

$$
\begin{aligned}
p_2 &= \frac{a}{2(b-c)} + \frac{c}{2(b-c)}\left(\frac{a+2cp_2}{2b}\right) \\
&= \frac{2ab + ac + 2c^2 p_2}{4b(b-c)}
\end{aligned}
$$

Rearranging for p_2:

$$
\begin{aligned}
p_2\left(1 - \frac{c^2}{2b(b-c)}\right) &= \frac{2ab+ac}{4b(b-c)} \\
p_2\left(\frac{2b^2 - 2bc - c^2}{2b(b-c)}\right) &= \frac{2ab+ac}{4b(b-c)} \\
p_2 &= p_3 = \frac{2ab+ac}{2(2b^2-2bc-c^2)} \qquad (13)
\end{aligned}
$$

This means that we can solve for p_1:

$$
\begin{aligned}
p_1 &= \frac{a}{2b} + \frac{2c}{2b}\left(\frac{2ab+ac}{2(2b^2-2bc-c^2)}\right) \\
&= \frac{a}{2b} + \frac{2abc+ac^2}{2b(2b^2-2bc-c^2)} \\
&= \frac{2ab^2 - 2abc - ac^2 + 2abc + ac^2}{2b(2b^2-2bc-c^2)} \\
p_1 &= \frac{ab}{(2b^2-2bc-c^2)} \qquad (14)
\end{aligned}
$$

Comparing equations (13) and (14), we note that $p_2 > p_1$. The multiproduct pricing implications of horizontal integration means price is higher in each chain property. The difference is:

$$
\begin{aligned}
p_{2,0} - p_{1,0} &= \frac{2ab+ac}{2(2b^2-2bc-c^2)} - \frac{ab}{(2b^2-2bc-c^2)} \\
&= \frac{ac}{2(2b^2-2bc-c^2)} \qquad (15)
\end{aligned}
$$

Given the prices derived in equations (13) and (14), we can find the value of each property type going into the last period, that is, the expected revenues by substituting them into equation (10).

For the franchised property:

$$\begin{aligned}
V_1 &= s_1 p_1 \\
&= \left(a - bp_1 + cp_2 + cp_3\right) p_1 \\
&= \left(a - bp_1 + 2c\left(p_1 + \frac{ac}{2\left(2b^2 - 2bc - c^2\right)}\right)\right) p_1 \\
&= ap_1 + (2c - b)p_1^2 + \frac{ac^2}{\left(2b^2 - 2bc - c^2\right)} p_1 \\
&= \left(\frac{2ab^2 - 2abc - ac^2 + ac^2}{2b^2 - 2bc - c^2}\right) p_1 + (2c - b)p_1^2 \\
&= \left(\frac{ab}{\left(2b^2 - 2bc - c^2\right)}\right)\left(\frac{2ab^2 - 2abc}{2b^2 - 2bc - c^2}\right) + \left(\frac{ab}{\left(2b^2 - 2bc - c^2\right)}\right)^2 (2c - b) \\
&= \frac{2a^2b^3 - 2a^2b^2c + 2a^2b^2c - a^2b^3}{\left(2b^2 - 2bc - c^2\right)^2} \\
&= \frac{2a^2b^3 - a^2b^3}{\left(2b^2 - 2bc - c^2\right)^2} \\
&= \frac{a^2b^3}{\left(2b^2 - 2bc - c^2\right)^2}
\end{aligned}$$

The value for the chain is

$$
\begin{aligned}
V_C &= 2s_2p_2 \\
&= 2\left(a - bp_2 + cp_1 + cp_3\right)p_2 \\
&= 2\left(a - bp_2 + cp_1 + cp_2\right)p_2 \\
&= 2\left(a - bp_2 + c\left(p_2 - \frac{ac}{2\left(2b^2 - 2bc - c^2\right)}\right) + cp_2\right)p_2 \\
&= 2ap_2 - 2bp_2^2 + 2cp_2^2 - \frac{ac^2}{\left(2b^2 - 2bc - c^2\right)}p_2 + 2cp_2^2 \\
&= 2\left[\left(a - \frac{ac^2}{2\left(2b^2 - 2bc - c^2\right)}\right)p_2 + \left(2c - b\right)p_2^2\right] \\
&= 2\left[\left(\frac{4ab^2 - 4abc - 2ac^2 - ac^2}{2\left(2b^2 - 2bc - c^2\right)}\right)p_2 + \left(2c - b\right)p_2^2\right] \\
V_C/2 &= \left(\frac{4ab^2 - 4abc - 3ac^2}{2\left(2b^2 - 2bc - c^2\right)}\right)\left(\frac{2ab + ac}{2\left(2b^2 - 2bc - c^2\right)}\right) + \left(2c - b\right)\left(\frac{2ab + ac}{2\left(2b^2 - 2bc - c^2\right)}\right)^2 \\
&= \frac{\left(4ab^2 - 4abc - 3ac^2\right)\left(2ab + ac\right) + \left(2c - b\right)\left(2ab + ac\right)^2}{4\left(2b^2 - 2bc - c^2\right)^2} \\
&= \frac{8a^2b^3 - 8a^2b^2c - 6a^2bc^2 + 4a^2b^2c - 4a^2bc^2 - 3a^2c^3 + \left(2c - b\right)\left(4a^2b^2 + 4a^2bc + a^2c^2\right)}{4\left(2b^2 - 2bc - c^2\right)^2} \\
&= \frac{8a^2b^3 - 8a^2b^2c - 6a^2bc^2 + 4a^2b^2c - 4a^2bc^2 - 3a^2c^3}{4\left(2b^2 - 2bc - c^2\right)^2} \\
&\quad + \frac{\left(8a^2b^2c + 8a^2bc^2 + 2a^2c^3\right) - \left(4a^2b^3 + 4a^2b^2c + a^2bc^2\right)}{4\left(2b^2 - 2bc - c^2\right)^2} \\
&= \frac{4a^2b^3 - a^2c^3 - 3a^2bc^2}{4\left(2b^2 - 2bc - c^2\right)^2} \\
&= \frac{a^2\left(4b^3 - c^3 - 3bc^2\right)}{4\left(2b^2 - 2bc - c^2\right)^2}
\end{aligned}
$$

Comparing the value functions for each property type, we can see that the value of the franchise property in the last period is greater than the value of each chain property iff:

$$
\begin{aligned}
\frac{a^2b^3}{\left(2b^2 - 2bc - c^2\right)^2} &> \frac{a^2\left(4b^3 - c^3 - 3bc^2\right)}{4\left(2b^2 - 2bc - c^2\right)^2} \\
4b^3 &> 4b^3 - c^3 - 3bc^2
\end{aligned}
$$

Since b and c are both positive, this inequality always holds and hence the value of the franchised hotel in the last period is greater than the chain. The intuition behind this is that the franchised property sets price in the last period to maximize value, whereas the chain maximizes the joint value of the two chain properties.

Price levels in the first period, the day before the date of stay, $t = T$

The objective function for each property in $t = T$ takes into account the fact that if the room remains unsold today, there is a positive expected value from selling it tomorrow. This is the opportunity cost of selling it today. For the franchised property:

$$\begin{aligned} V_{T,F} &= s_T p_T + (1 - s_T) V_{1,0} \\ \frac{dV}{dp} &= s + \frac{ds}{dp} p - \frac{ds}{dp} V_{1,0} \\ &= a - bp_1 + cp_2 + cp_3 - bp_1 + bV_{1,0} \end{aligned}$$

where time subscripts will be included in this section only when referring to the last period. The first order condition, setting $p_2 = p_3$, is

$$\begin{aligned} 2bp_1 &= a + 2cp_2 + bV_{1,0} \\ p_1 &= \frac{a + 2cp_2}{2b} + \frac{V_{1,0}}{2} \end{aligned} \tag{16}$$

For the chain, the value function in the second to last period, including the value of both chain hotels, is:

$$\begin{aligned} V_{T,C} &= s_2 p_2 + (1 - s_2) V_{2,0} + s_3 p_3 + (1 - s_3) V_{3,0} \\ \frac{dV}{dp_2} &= s_2 + \frac{ds_2}{dp_2} p_2 - \frac{ds_2}{dp_2} V_{2,0} + \frac{ds_3}{dp_2} p_3 - \frac{ds_3}{dp_2} V_{3,0} \\ &= a - bp_2 + cp_1 + cp_3 - bp_2 + bV_{2,0} + cp_3 - cV_{3,0} \\ &= a - 2bp_2 + cp_1 + 2cp_3 + bV_{2,0} - cV_{3,0} \end{aligned}$$

The first order condition is:

$$\begin{aligned} 2bp_2 &= a + cp_1 + 2cp_3 + bV_{2,0} - cV_{3,0} \\ p_2 &= \frac{a + cp_1 + 2cp_3}{2b} + \frac{bV_{2,0} - cV_{3,0}}{2b} \end{aligned}$$

By symmetry, $V_{2,0} = V_{3,0}$ and setting $p_2 = p_3$ again gives:

$$\begin{aligned}
p_2\left(1-\frac{c}{b}\right) &= \frac{a+cp_1}{2b}+\frac{V_{2,0}\,(b-c)}{2b}\\
p_2\left(\frac{b-c}{b}\right) &= \frac{a+cp_1}{2b}+\frac{V_{2,0}\,(b-c)}{2b}\\
p_2 &= \frac{a+cp_1}{2\,(b-c)}+\frac{V_{2,0}}{2}
\end{aligned}$$

substituting in for p_1 gives:

$$\begin{aligned}
p_2 &= \frac{a}{2\,(b-c)}+\frac{c}{2\,(b-c)}\left(\frac{a+2cp_2}{2b}+\frac{V_1}{2}\right)+\frac{V_{2,0}}{2}\\
p_2 &= \frac{2ab+ac}{4b\,(b-c)}+\frac{c^2}{2b\,(b-c)}p_2+\frac{cV_1}{4\,(b-c)}+\frac{V_{2,0}}{2}\\
p_2\left(1-\frac{c^2}{2b\,(b-c)}\right) &= \frac{2ab+ac}{4b\,(b-c)}+\frac{cV_1}{4\,(b-c)}+\frac{V_{2,0}}{2}\\
p_2\left(\frac{2b\,(b-c)-c^2}{2b\,(b-c)}\right) &= \frac{2ab+ac}{4b\,(b-c)}+\frac{cV_1}{4\,(b-c)}+\frac{V_{2,0}}{2}\\
p_2 &= \frac{2ab+ac}{2\,(2b^2-2bc-c^2)}+\frac{2b\,(b-c)\,cV_1}{4\,(b-c)\,(2b^2-2bc-c^2)}+\frac{2b\,(b-c)\,V_{2,0}}{2\,(2b^2-2bc-c^2)}\\
p_{2,T} &= p_{2,0}+\frac{bcV_1}{2\,(2b^2-2bc-c^2)}+\frac{2b\,(b-c)\,V_{2,0}}{2\,(2b^2-2bc-c^2)}
\end{aligned}$$

Returning now to the price of the franchised hotel in the next to last period:

$$\begin{aligned}
p_1 &= \frac{a+2cp_2}{2b}+\frac{V_1}{2}\\
&= \frac{a}{2b}+\frac{c}{b}\left[\frac{2ab+ac}{2\,(2b^2-2bc-c^2)}+\frac{bcV_1}{2\,(2b^2-2bc-c^2)}+\frac{2b\,(b-c)\,V_{2,0}}{2\,(2b^2-2bc-c^2)}\right]+\frac{V_1}{2}\\
&= p_{1,0}+\frac{bc^2V_1}{2\,(2b^2-2bc-c^2)}+\frac{2bc\,(b-c)\,V_{2,0}}{2\,(2b^2-2bc-c^2)}+\frac{V_1}{2}\\
&= p_{1,0}+\frac{bc^2V_1+2bc\,(b-c)\,V_{2,0}+V_1\,(2b^2-2bc-c^2)}{2\,(2b^2-2bc-c^2)}\\
&= p_{1,0}+\frac{V_1\,(bc^2+2b^2-2bc-c^2)+2bc\,(b-c)\,V_{2,0}}{2\,(2b^2-2bc-c^2)}\\
&= p_{1,0}+\frac{V_1\,(2b^2-2bc+c^2(b-1))+2bc\,(b-c)\,V_{2,0}}{2\,(2b^2-2bc-c^2)}
\end{aligned}$$

A comparison of price trends

We note that we can decompose the price in the next to last period in a chain property into three terms:

$$p_{2,T} = p_{2,0} + \left[\frac{bcV_1}{2\left(2b^2-2bc-c^2\right)} + \frac{2b\left(b-c\right)V_{2,0}}{2\left(2b^2-2bc-c^2\right)} - \frac{V_{2,0}}{2}\right] + \frac{V_{2,0}}{2}$$

and the change in price between the two periods is hence:

$$\begin{aligned} p_{2,T} - p_{2,0} &= \left[\frac{bcV_1}{2\left(2b^2-2bc-c^2\right)} + \frac{2b\left(b-c\right)V_{2,0}}{2\left(2b^2-2bc-c^2\right)} - \frac{V_{2,0}}{2}\right] + \frac{V_{2,0}}{2} \\ &= \left[\frac{bcV_1}{2\left(2b^2-2bc-c^2\right)} + \frac{V_{2,0}\left(2b^2-2bc-2b^2+2bc+c^2\right)}{2\left(2b^2-2bc-c^2\right)}\right] + \frac{V_{2,0}}{2} \\ &= \left[\frac{bcV_1}{2\left(2b^2-2bc-c^2\right)} + \frac{c^2V_{2,0}}{2\left(2b^2-2bc-c^2\right)}\right] + \frac{V_{2,0}}{2} \end{aligned} \tag{17}$$

The price in the franchised hotel has three equivalent terms:

$$p_{1,T} = p_{1,0} + \left[\frac{bc^2V_1}{2\left(2b^2-2bc-c^2\right)} + \frac{2bc\left(b-c\right)V_{2,0}}{2\left(2b^2-2bc-c^2\right)}\right] + \frac{V_{1,0}}{2}$$

and the change in price between the two periods is hence:

$$p_{1,T} - p_{1,0} = \left[\frac{bc^2V_1}{2\left(2b^2-2bc-c^2\right)} + \frac{2bc\left(b-c\right)V_{2,0}}{2\left(2b^2-2bc-c^2\right)}\right] + \frac{V_{1,0}}{2} \tag{18}$$

We know that, for reasonable assumptions on the relative magnitudes of b and c, the second term on the right hand side of equation (18) is larger than the equivalent term in equation (17), since $V_{1,0} > V_{2,0}$. This is the direct effect on the earlier price of the fact that there is now an opportunity cost associated with selling today, and this cost is greater for the franchised hotel. Hence the franchised hotel raises price by a larger amount due to this effect.

The first term on the right hand side of both equations (17) and (18) is the effect on earlier prices of the response of property i's price to the fact that both other properties will be setting higher prices due to the opportunity cost effect. This term will be larger for the franchised property if:

$$
\begin{aligned}
\frac{bc^2V_1}{2(2b^2-2bc-c^2)}+\frac{2bc(b-c)V_{2,0}}{2(2b^2-2bc-c^2)} &> \frac{bcV_1}{2(2b^2-2bc-c^2)}+\frac{c^2V_{2,0}}{2(2b^2-2bc-c^2)}\\
bc^2V_1+2b^2cV_{2,0}-2bc^2V_{2,0} &> bcV_1+c^2V_{2,0}\\
bc^2V_1-bcV_1 &> 2bc^2V_{2,0}+c^2V_{2,0}-2b^2cV_{2,0}\\
V_1c(bc-b) &> V_{2,0}c(2bc+c-b)\\
V_1(bc-b) &> V_{2,0}(2bc+c-b)
\end{aligned}
$$

What does this tell us about the overall relative change in price?

The direct change in opportunity cost effect leads the franchise to cut price more, but the indirect effect of the change in opportunity cost on prices can lead the chain properties to cut prices by more (if the last inequality does not hold). What is the net effect? Multiplying the second term in each of equations (17) and (18) by the denominator of the first term, we see that the overall change in price in the franchised property is greater than in each chain property iff:

$$
\begin{aligned}
bc^2V_1+2b^2cV_{2,0}-2bc^2V_{2,0}+V_{1,0}\left(2b^2-2bc-c^2\right) &> bcV_1+c^2V_{2,0}+V_{2,0}\left(2b^2-2bc-c^2\right)\\
V_1\left(bc^2+2b^2-2bc-c^2-bc\right) &> V_{2,0}\left(c^2+2b^2-2bc-c^2-2b^2c+2bc^2\right)\\
V_1\left(bc^2+2b^2-3bc-c^2\right) &> V_{2,0}\left(2b^2-2bc-2b^2c+2bc^2\right)\\
V_1\left(2b^2-3bc+bc^2-c^2\right) &> 2bV_{2,0}\left(b-c-bc+c^2\right)
\end{aligned}
$$

Substituting in for V_1 and $V_{2,0}$, multiplying both sides by the common denominator and dividing both sides by a^2 gives:

$$\begin{aligned}
4b^3\left(2b^2-3bc+bc^2-c^2\right) &> 2b\left(4b^3-c^3-3bc^2\right)(1-c)(b-c)\\
2b^2\left(2b^2-3bc+bc^2-c^2\right) &> \left(4b^3-c^3-3bc^2\right)(1-c)(b-c)\\
b(4b^3-6b^2c+2b^2c^2-2bc^2) &> b\left(4b^3-c^3-3bc^2\right)(1-c)-c\left(4b^3-c^3-3bc^2\right)(1-c)\\
b(4b^3-6b^2c+2b^2c^2-2bc^2) &> b\left(4b^3-c^3-3bc^2\right)-c\left(4b^3-c^3-3bc^2\right)(b+1-c)\\
b(2b^2c^2-6b^2c+bc^2+c^3) &> -c\left(4b^3-c^3-3bc^2\right)(b+1-c)\\
bc(2b^2c-6b^2+bc+c^2) &> -c\left(4b^3-c^3-3bc^2\right)(b+1-c)\\
b(2b^2c-6b^2+bc+c^2) &> -\left(4b^3-c^3-3bc^2\right)(b+1-c)\\
4b^3-c^3-3bc^2 &> -\frac{b(b^2(2c-6)+c(b+c))}{(1+b-c)}\\
4b^3-c^3-3bc^2 &> \frac{b(b^2(6-2c)-c(b+c))}{(1+b-c)} \qquad (19)
\end{aligned}$$

While this inequality is hard to simplify, simulations show that it never holds when $b < 0.5$, noting that b and c are both between 0 and 1. That is for a reasonable restriction on the parameter value of own price elasticity, chain hotels cut prices faster than franchised hotels. Although the change in price to due to the change in opportunity cost is larger for the franchise, this is outweighed by the fact that the chain increases its price disproportionately in its strategic reaction to the franchises's larger change in opportunity cost. Figure 7 demonstrates that chain managed properties cut prices by more than the franchised property for reasonable values of b and c, whereas Figure 6 shows that the opposite is true in the two hotel case with asymmetric information and uncertainty aversion. Multiproduct pricing effects appear unable to explain the empirical result that franchises cut prices faster, once the game is taken into account.

Three hotel two period pricing game with uncertainty aversion

In this subsection, we introduce information asymmetry together with uncertainty aversion in the three hotel model. In a given market there are three properties that are symmetrically differentiated. Property 1 is a franchise and properties 2 and 3 are horizontally integrated in a chain. Again, there are two periods $t = 0$ and $t = T$. The prior day is period T. In period $t \in (T, 0)$, the probability that an empty room in hotel i is reserved is given by the linear function:

$$s_{i,t} = \widetilde{a}_{i,t} - bp_{i,t} + \sum_{j \neq i} cp_{j,t} \tag{20}$$

As in the model in the main body of the text, the franchise property acts as if $a_{i,t} = a$ in both periods, where a is the worst an adversarial nature can produce. Each of the chain properties sets their price as if $\widetilde{a}_{i,t} = a$ in the first period and $\widetilde{a}_{i,t} = \overline{a}$ in the final period, $\overline{a} > a$.

Price levels in the final period, on the date of stay, $t = 0$

For the franchise (dropping time subscripts for convenience):

$$\begin{aligned}
V_1 &= s_1 p_1 + (1 - s_1)0 \\
\frac{dV_1}{dp_1} &= s_1 + \frac{ds}{dp_1} p_1 \\
&= a - bp_1 + c\widehat{p}_2 + c\widehat{p}_3 - bp_1
\end{aligned}$$

The first order condition, together with the symmetry of the two chain properties, gives:

$$\begin{aligned}
2bp_1 &= a + 2c\widehat{p}_2 \\
p_1 &= \frac{a + 2c\widehat{p}_2}{2b}
\end{aligned} \tag{21}$$

For the chain, the objective is to maximize the joint revenues of the two chain properties, taking the demand spillovers between these properties into account.

$$\begin{aligned}
V_C &= s_2 p_2 + s_3 p_3 + (1 - s_2)0 + (1 - s_3)0 \\
\frac{dV}{dp_2} &= s_2 + \frac{ds_2}{dp_2} p_2 + \frac{ds_3}{dp_2} p_3 \\
&= \overline{a} - bp_2 + cp_1 + cp_3 - bp_2 + cp_3 \\
&= \overline{a} - 2bp_2 + 2cp_3 + cp_1 \\
&= \overline{a} - 2(b - c)p_2 + cp_1
\end{aligned}$$

due to symmetry again. This gives:

$$p_2 = \frac{\overline{a}}{2(b - c)} + \frac{cp_1}{2(b - c)} \tag{22}$$

We note that the franchise's conservative estimate of the demand curve for the chain which generates the franchise's estimate of the price at each chain hotel, $\widehat{p}_2$, is equivalent to equation (22) but derived using the probability function with the intercept equal to a and not $\overline{a}$. Making this substitution and then substituting for p_2 in equation (21) gives:

$$
\begin{aligned}
p_1 &= \frac{a}{2b} + \frac{2c}{2b}\left[\frac{a}{2(b-c)} + \frac{cp_1}{2(b-c)}\right] \\
p_1\left(1 - \frac{2c^2}{4b(b-c)}\right) &= \frac{2a(b-c)+2ac}{4b(b-c)} \\
p_1\left(\frac{4b^2-4bc-2c^2}{4b(b-c)}\right) &= \frac{2a(b-c)+2ac}{4b(b-c)} \\
p_1\left(\frac{4b^2-4bc-2c^2}{4b(b-c)}\right) &= \frac{2ab}{4b(b-c)} \\
p_1 &= \frac{2ab}{4b^2-4bc-2c^2} \\
p_1 &= \frac{ab}{2b^2-2bc-c^2} \qquad (23)
\end{aligned}
$$

Since the chain can anticipate the franchise's actions due to the fact that its information set includes knowledge of the franchise's less precise estimate of demand, the expression for p_1 given in equation (23) can be substituted into the expression for p_2 to give:

$$
\begin{aligned}
p_2 &= \frac{\overline{a}}{2(b-c)} + \frac{c}{2(b-c)}\left(\frac{ab}{2b^2-2bc-c^2}\right) \\
p_2 &= \frac{\overline{a}\left(2b^2-2bc-c^2\right)+abc}{2(b-c)\left(2b^2-2bc-c^2\right)} \qquad (24)
\end{aligned}
$$

Comparing the price levels of each hotel given in equations (23) and (24), the price of each chain hotel is higher iff:

$$
\begin{aligned}
\overline{a}\left(2b^2-2bc-c^2\right)+abc &> ab2(b-c) \\
2\overline{a}b^2-2\overline{a}bc-\overline{a}c^2+abc &> 2ab^2-2abc \\
2b^2\left(\overline{a}-a\right)-2bc\left(\overline{a}-a\right) &> c(\overline{a}c-ab) \\
\left(\overline{a}-a\right)\left(b\left(2b-c\right)\right) &> c(\overline{a}c-ab)
\end{aligned}
$$

This seems likely to hold for $\overline{a} > a$ and $b > c$.

Price levels in the first period, the day before the date of stay, $t = T$

As in the two hotel game, none of the properties knows the extent to which the chain's information about demand will increase in precision tomorrow. For the franchised property:

$$\begin{aligned} V_{T,F} &= s_T p_T + (1 - s_T)EV_{1,0} \\ \frac{dV}{dp} &= s + \frac{ds}{dp}p - \frac{ds}{dp}V_{1,0} \\ &= a - bp_1 + cp_2 + cp_3 - bp_1 + bEV_{1,0} \end{aligned}$$

where time subscripts will be included in this section only when referring to the last period. The first order condition, setting $p_2 = p_3$, is

$$\begin{aligned} 2bp_1 &= a + 2cp_2 + bEV_{1,0} \\ p_1 &= \frac{a + 2cp_2}{2b} + \frac{EV_{1,0}}{2} \end{aligned} \tag{25}$$

For the chain in this period, their information about demand is the same as the information known by the franchise. The value function in the second to last period, including the value of both chain hotels, is hence:

$$\begin{aligned} V_{T,C} &= s_2 p_2 + (1 - s_2)EV_{2,0} + s_3 p_3 + (1 - s_3)EV_{3,0} \\ \frac{dV}{dp_2} &= s_2 + \frac{ds_2}{dp_2}p_2 - \frac{ds_2}{dp_2}EV_{2,0} + \frac{ds_3}{dp_2}p_3 - \frac{ds_3}{dp_2}EV_{3,0} \\ &= a - bp_2 + cp_1 + cp_3 - bp_2 + bEV_{2,0} + cp_3 - cEV_{3,0} \\ &= a - 2bp_2 + cp_1 + 2cp_3 + bEV_{2,0} - cEV_{3,0} \end{aligned}$$

Due to symmetry, the first order condition is:

$$\begin{aligned} 2bp_2 - 2cp_2 &= a + cp_1 + bEV_{2,0} - cEV_{2,0} \\ p_2 2(b - c) &= a + cp_1 + (b - c)EV_{2,0} \\ p_2 &= \frac{a}{2(b - c)} + \frac{cp_1}{2(b - c)} + \frac{EV_{2,0}}{2} \end{aligned}$$

Substituting in for p_1 gives:

$$
\begin{aligned}
p_2 &= \frac{a}{2(b-c)} + \frac{c}{2(b-c)}\left(\frac{a+2cp_2}{2b} + \frac{EV_{1,0}}{2}\right) + \frac{EV_{2,0}}{2} \\
&= \frac{2ab}{4b(b-c)} + \frac{ca+2c^2p_2}{4b(b-c)} + \frac{cEV_{1,0}}{4(b-c)} + \frac{EV_{2,0}}{2} \\
p_2 &= \frac{2ab+ac}{4b(b-c)} + \frac{2c^2}{4b(b-c)}p_2 + \frac{cEV_1}{4(b-c)} + \frac{EV_{2,0}}{2} \\
p_2\left(1 - \frac{2c^2}{4b(b-c)}\right) &= \frac{2ab+ac}{4b(b-c)} + \frac{cEV_1}{4(b-c)} + \frac{EV_{2,0}}{2} \\
p_2\left(\frac{4b^2-4bc-2c^2}{4b(b-c)}\right) &= \frac{2ab+ac}{4b(b-c)} + \frac{cV_1}{4(b-c)} + \frac{V_{2,0}}{2} \\
p_2 &= \frac{2ab+ac}{4b^2-4bc-2c^2} + \frac{4b(b-c)cV_1}{4(b-c)(4b^2-4bc-2c^2)} + \frac{2b(b-c)V_{2,0}}{2(4b^2-4bc-2c^2)} \\
p_{2,T} &= \frac{2ab+ac}{4b^2-4bc-2c^2} + \frac{bcV_1}{4b^2-4bc-2c^2} + \frac{2b(b-c)V_{2,0}}{4b^2-4bc-2c^2} \qquad (26)
\end{aligned}
$$

Having found an expression for the price of each chain hotel in the earlier period, we can return now to the price of the franchised hotel. We note that both the franchised and chain hotels have the same estimate of the future value functions of each property. Unlike in the two hotel game, however, $EV_{2,0} \neq EV_{1,0}$ due to anticipated joint pricing across chain properties in the last period.

$$
\begin{aligned}
p_1 &= \frac{a+2cp_2}{2b} + \frac{V_1}{2} \\
&= \frac{a}{2b} + \frac{2c}{2b}\left[\frac{2ab+ac}{4b^2-4bc-2c^2} + \frac{bcV_1}{4b^2-4bc-2c^2} + \frac{2b(b-c)V_{2,0}}{4b^2-4bc-2c^2}\right] + \frac{V_1}{2} \\
&= \frac{4ab^2-4abc-2ac^2}{2b(4b^2-4bc-2c^2)} + \frac{4abc+2ac^2}{2b(4b^2-4bc-2c^2)} + \frac{2bc^2V_1 + 4bc(b-c)V_{2,0}}{2b(4b^2-4bc-2c^2)} + \frac{V_1}{2} \\
&= \frac{4ab^2}{2b(4b^2-4bc-2c^2)} + \frac{2bc^2V_1 + 4bc(b-c)V_{2,0} + V_1b(4b^2-4bc-2c^2)}{2b(4b^2-4bc-2c^2)} \\
&= \frac{4ab^2}{2b(4b^2-4bc-2c^2)} + \frac{V_{2,0}4bc(b-c) + V_1b(4b^2-4bc)}{2b(4b^2-4bc-2c^2)} \\
&= \frac{ab}{(2b^2-2bc-c^2)} + \frac{V_{2,0}4bc(b-c) + V_14b^2(b-c)}{2b(4b^2-4bc-2c^2)} \\
&= \frac{ab}{(2b^2-2bc-c^2)} + \frac{V_{2,0}2c(b-c) + V_12b(b-c)}{(4b^2-4bc-2c^2)} \\
p_{1,T} &= \frac{ab}{(2b^2-2bc-c^2)} + \frac{(b-c)(2cV_{2,0}+2bV_1)}{(2b^2-2bc-c^2)} \qquad (27)
\end{aligned}
$$

A comparison of price trends

Comparing equations (23) and (27), the change in price at the franchise is given by:

$$\begin{aligned}\Delta F &= \frac{ab}{(2b^2-2bc-c^2)}+\frac{(b-c)(2cV_{2,0}+2bV_1)}{(2b^2-2bc-c^2)}-\frac{ab}{(2b^2-2bc-c^2)} \\ &= \frac{(b-c)(2cV_{2,0}+2bV_1)}{(2b^2-2bc-c^2)} \end{aligned} \tag{28}$$

As in the two hotel case, we see that the price is lower in the last period for the franchise due only to the change in opportunity cost. The opportunity cost of not selling in each period falls from the expected value of selling it on the last day to zero.

The change in price in each chain hotel is given by the difference between equations (26) and (24):

$$\begin{aligned}\Delta C &= \frac{2ab+ac}{4b^2-4bc-2c^2}+\frac{bcV_1}{4b^2-4bc-2c^2}+\frac{2b(b-c)V_{2,0}}{4b^2-4bc-2c^2}-\frac{\overline{a}(2b^2-2bc-c^2)+abc}{2(b-c)(2b^2-2bc-c^2)} \\ &= \frac{2ab(b-c)+ac(b-c)-\overline{a}(2b^2-2bc-c^2)-abc}{2(b-c)(2b^2-2bc-c^2)}+\frac{bcV_1+2b(b-c)V_{2,0}}{4b^2-4bc-2c^2} \\ &= \frac{2ab^2-2abc+abc-ac^2-\overline{a}(2b^2-2bc-c^2)-abc}{2(b-c)(2b^2-2bc-c^2)}+\frac{bcV_1+2b(b-c)V_{2,0}}{4b^2-4bc-2c^2} \\ &= \frac{a(2b^2-2bc-c^2)-\overline{a}(2b^2-2bc-c^2)}{2(b-c)(2b^2-2bc-c^2)}+\frac{bcV_1+2b(b-c)V_{2,0}}{4b^2-4bc-2c^2} \\ &= \frac{bcV_1+2b(b-c)V_{2,0}}{4b^2-4bc-2c^2}-\frac{\overline{a}-a}{2(b-c)} \end{aligned} \tag{29}$$

The franchise cuts its price by a greater amount than either of the chain managed hotels iff $\Delta F > \Delta C$:

$$\begin{aligned}\frac{(b-c)(2cV_{2,0}+2bV_1)}{(2b^2-2bc-c^2)} &> \frac{bcV_1+2b(b-c)V_{2,0}}{4b^2-4bc-2c^2}-\frac{\overline{a}-a}{2(b-c)} \\ \frac{\overline{a}-a}{2(b-c)} &> \frac{bcV_1+2b(b-c)V_{2,0}-2(b-c)(2cV_{2,0}+2bV_1)}{4b^2-4bc-2c^2} \\ \frac{\overline{a}-a}{2(b-c)} &> \frac{V_1(bc-4b(b-c))+V_{2,0}(2b(b-c)-4c(b-c))}{4b^2-4bc-2c^2} \\ \frac{\overline{a}-a}{2(b-c)} &> \frac{V_1(5bc-4b^2)+V_{2,0}(2b^2-2bc-4bc+4c^2)}{4b^2-4bc-2c^2} \\ \frac{\overline{a}-a}{2(b-c)} &> \frac{V_1(5bc-4b^2)+V_{2,0}(2b^2-6bc+4c^2)}{4b^2-4bc-2c^2} \end{aligned}$$

We note that $EV_{1,0}$ and $EV_{2,0}$ are equivalent to the expected values of each property type in the last period derived in the three hotel no uncertainty game set out in the first part of the appendix. This is because each property's estimates of these values is made when both are relatively uninformed in $t = T$.

$$EV_{2,0} = \frac{a^2\left(4b^2 - 3bc^2 - c^3\right)}{4\left(2b^2 - 2bc - c^2\right)^2}$$

$$EV_{1,0} = \frac{a^2 b^3}{\left(2b^2 - 2bc - c^2\right)^2} = \frac{4a^2 b^3}{4\left(2b^2 - 2bc - c^2\right)^2}$$

Substituting these expected values into the inequality characterizing when $\Delta F > \Delta C$ tells us that the change in price at the franchised hotel is greater than the price change in each chain property iff:

$$\begin{aligned}
\frac{\overline{a} - a}{2(b-c)} &> \frac{V_1\left(5bc - 4b^2\right) + V_{2,0}\left(2b^2 - 6bc + 4c^2\right)}{4b^2 - 4bc - 2c^2} \\
\frac{\overline{a} - a}{2(b-c)} &> \frac{4a^2b^3\left(5bc - 4b^2\right) + a^2\left(4b^2 - 3bc^2 - c^3\right)\left(2b^2 - 6bc + 4c^2\right)}{8\left(2b^2 - 2bc - c^2\right)^3} \\
\frac{\overline{a} - a}{2(b-c)} &> \frac{2a^2b^3\left(5bc - 4b^2\right) + a^2\left(4b^2 - 3bc^2 - c^3\right)\left(b^2 - 3bc + 2c^2\right)}{4\left(2b^2 - 2bc - c^2\right)^3} \\
\frac{\overline{a} - a}{(b-c)} &> \frac{2a^2b^3\left(5bc - 4b^2\right) + a^2\left(4b^2 - 3bc^2 - c^3\right)\left(b^2 - 3bc + 2c^2\right)}{2\left(2b^2 - 2bc - c^2\right)^3} \\
\frac{\overline{a} - a}{(b-c)} &> \frac{a^2\left(b^4\left(4 + 10c - 8b\right) + c^3\left(8b^2 - 3bc - 2c^2\right) + b^2c\left(8c - 12b - 3bc\right)\right)}{2\left(2b^2 - 2bc - c^2\right)^3} \\
\frac{\overline{a} - a}{a^2} &> \frac{(b-c)\left(b^4\left(4 + 10c - 8b\right) + c^3\left(8b^2 - 3bc - 2c^2\right) + b^2c\left(8c - 12b - 3bc\right)\right)}{2\left(2b^2 - 2bc - c^2\right)^3} \qquad (30)
\end{aligned}$$

What can we learn from this inequality? For any $a > 0$, the larger is $\overline{a}$ the more likely it is that inequality holds. This is because the increased precision in the second period leads the chain to increase its prices relative to the franchise by a larger amount. The denominator of the right hand side is very small so, generally, the parameter values for b and c need to be such that the numerator is negative for the inequality to hold. Figures 8 to 10 reveal the pairs of parameter values for b and c under which the inequality holds given that the left hand side of the inequality is equal to 0.1, 0.2 and 0.3, respectively. We note that we are mainly interested in the area under the 45 degree line, since we expect b to be greater than c. The non-shaded regions reveal where the inequality holds meaning the franchise cuts prices faster than each chain hotel despite the multiproduct pricing effect leading the chains to cut prices by more. The larger the left hand side of inequality (30), the larger the set of parameter values for b and c for which the inequality holds.

Figures for the appendix

In each figure, b and c vary between 0 and 0.5. b is on the x-axis and c is on the y-axis. The non-shaded areas represent the regions where the relevant inequality holds, that is franchises cut prices faster than chain hotels. There are five figures representing the following cases:

6. Two hotel case with uncertainty. Note: franchise always cuts price by more for $b > c$. This is the model set out in the main text in the paper.

7. Three hotels no uncertainty (first appendix example). Note: chains always cut prices faster for $b > c$.

8. Three hotel case with uncertainty and joint pricing (second appendix example). Non-shaded areas are when right hand side of inequality is less than 0.1 (threshold value of $(\overline{a} - a)/a^2$).

9. Three hotel case with uncertainty and joint pricing (second appendix example). Non-shaded areas are when right hand side of inequality is less than 0.2 (threshold value of $(\overline{a} - a)/a^2$). The share of non-shaded region increases with $\overline{a}$ for fixed a.

10. Three hotel case with uncertainty and joint pricing (second appendix example). Non-shaded areas are when right hand side of inequality is less than 0.3 (threshold value of $(\overline{a} - a)/a^2$). The share of non-shaded region increases with $\overline{a}$ for fixed a.

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Table 1: Summary statistics about hotel characteristics
Source: Smith Travel Research, property websites.

Data Set	Brand	Number of properties	% Franchised	Rooms, #	Meeting space, sq ft	Distance to HQ, miles	Vacaction facilities	Conference facilities
First Data Set	Four Points	71	94%	172	7732	1529	1%	1%
	Hyatt	101	11%	536	37494	1613	18%	63%
	Marriott	260	55%	403	24983	1615	10%	37%
	Radisson	142	94%	227	11703	1352	1%	11%
	Sheraton	176	74%	381	27833	1719	3%	36%
	Westin	77	49%	440	29643	1818	13%	58%
Second Data Set	Four Points	70	93%	174	7942	1561	1%	3%
	Hyatt	96	10%	533	36804	1596	20%	65%
	Marriott	302	55%	401	25756	1606	11%	36%
	Radisson	143	93%	229	11637	1381	1%	12%
	Sheraton	169	73%	371	26718	1736	4%	36%
	Westin	80	49%	452	32081	1823	14%	59%
Third Data Set	Four Points	65	92%	179	7088	1557	0%	3%
	Hyatt	100	11%	531	36290	1630	19%	63%
	Marriott	309	52%	403	25191	1616	10%	35%
	Radisson	137	93%	235	12406	1388	1%	14%
	Sheraton	169	73%	375	26824	1713	4%	36%
	Westin	84	46%	445	32016	1816	14%	58%

Table 2: Summary statistics (in US dollars) for the price data
Source: property websites.

First Data Set			Min price					Max price					Number of prices offered				
Brand	Properties	Day	# Observations	Mean	Standard Deviation	Minimum	Maximum	# Observations	Mean	Standard Deviation	Minimum	Maximum	# Observations	Mean	Standard Deviation	Minimum	Maximum
Four Points	Chain Managed	First Day	4	118	46	70	175	4	171	40	115	205	4	4.00	0.82	3	5
		Last Day (Date of Stay)	5	117	36	65	150	5	163	27	115	180	4	4.60	1.5	3	7
Hyatt	Chain Managed	First Day	90	215	60	89	389	90	321	149	89	1115	90	6.00	3.83	1	29
		Last Day (Date of Stay)	88	201	62	99	499	88	319	165	149	1115	88	6.35	3.39	2	20
Marriott	Chain Managed	First Day	117	212	53	109	409	117	353	162	149	900	117	5.44	3.9	1	25
		Last Day (Date of Stay)	128	225	61	109	529	128	327	140	149	819	128	4.51	3.13	1	20
Radisson	Chain Managed	First Day	9	159	47	89	229	9	225	97	125	439	9	5.67	1.66	4	7
		Last Day (Date of Stay)	4	124	53	85	199	4	201	142	99	409	4	5.25	1.71	3	7
Sheraton	Chain Managed	First Day	45	188	59	95	359	45	287	115	130	623	45	6.00	3.31	2	15
		Last Day (Date of Stay)	44	182	55	99	359	44	313	223	159	1500	44	5.66	2.71	2	12
Westin	Chain Managed	First Day	39	227	56	123	350	39	375	237	219	1679	39	5.77	2.87	1	16
		Last Day (Date of Stay)	40	209	47	89	341	40	376	192	210	1219	40	6.30	2.43	2	12
Four Points	Franchised	First Day	67	131	40	65	295	67	194	95	95	660	67	4.63	2.07	1	10
		Last Day (Date of Stay)	64	119	36	65	295	64	188	65	90	400	64	4.88	2.16	1	10
Hyatt	Franchised	First Day	11	184	39	99	249	11	232	59	159	359	11	4.45	2.46	1	9
		Last Day (Date of Stay)	11	170	43	119	269	11	220	67	159	379	11	4.36	2.54	2	10
Marriott	Franchised	First Day	143	196	50	109	365	143	283	120	139	969	143	4.38	4.11	1	41
		Last Day (Date of Stay)	148	195	47	109	365	148	276	123	145	900	148	3.88	3.88	1	40
Radisson	Franchised	First Day	133	130	40	67	389	133	217	101	99	999	133	6.54	2.58	1	16
		Last Day (Date of Stay)	63	116	26	74	179	63	194	63	107	414	63	6.03	2.64	1	13
Sheraton	Franchised	First Day	131	171	52	79	499	131	272	178	89	1999	131	5.06	2.62	1	16
		Last Day (Date of Stay)	129	159	40	79	279	129	262	182	89	1999	129	4.50	2.3	1	14
Westin	Franchised	First Day	38	289	89	89	645	38	419	283	219	1599	38	5.66	2.51	2	14
		Last Day (Date of Stay)	37	203	69	89	495	37	344	184	179	1015	37	5.46	2.52	2	13

Second Data Set			Min price					Max price					Number of prices offered				
Brand	Properties	Day	# Observations	Mean	Standard Deviation	Minimum	Maximum	# Observations	Mean	Standard Deviation	Minimum	Maximum	# Observations	Mean	Standard Deviation	Minimum	Maximum
Four Points	Chain Managed	First Day	5	133	44	60	175	5	195	50	115	240	5	5.20	1.79	4	8
		Last Day (Date of Stay)	4	116	47	65	175	4	168	58	110	235	4	4.25	2.36	1	6
Hyatt	Chain Managed	First Day	86	234	69	89	432	86	342	159	89	1105	86	5.94	3.76	1	27
		Last Day (Date of Stay)	79	233	69	99	470	79	331	142	179	1105	79	5.59	3.26	1	20
Marriott	Chain Managed	First Day	137	233	67	119	449	137	350	154	149	900	137	5.03	4.38	1	31
		Last Day (Date of Stay)	129	238	64	129	479	129	331	134	149	819	129	4.17	3.7	1	26
Radisson	Chain Managed	First Day	10	148	44	94	219	10	231	90	129	429	10	7.40	1.71	4	9
		Last Day (Date of Stay)	4	172	80	116	289	4	253	164	164	499	4	7.25	1.71	5	9
Sheraton	Chain Managed	First Day	45	204	66	99	380	45	309	129	159	778	45	5.49	3	1	16
		Last Day (Date of Stay)	37	196	51	109	315	37	195	115	159	770	37	6.06	3.15	2	16
Westin	Chain Managed	First Day	41	257	59	89	429	41	391	167	239	1219	41	6.17	3.03	1	14
		Last Day (Date of Stay)	37	271	89	99	649	37	420	275	230	1900	37	5.97	3.12	1	13
Four Points	Franchised	First Day	65	135	38	70	295	65	205	88	100	660	65	5.15	2.25	1	10
		Last Day (Date of Stay)	58	133	37	70	255	58	211	91	100	660	58	5.36	2.4	1	10
Hyatt	Franchised	First Day	10	199	57	119	289	10	242	70	169	399	10	4.10	1.73	2	6
		Last Day (Date of Stay)	8	197	56	139	289	8	244	71	174	399	8	4.25	1.98	2	6
Marriott	Franchised	First Day	165	196	47	109	379	165	284	130	145	969	165	4.21	3.02	1	24
		Last Day (Date of Stay)	157	206	60	104	699	157	273	108	139	900	157	3.52	2.52	1	19
Radisson	Franchised	First Day	133	135	42	74	389	133	219	100	89	999	133	6.76	2.73	1	17
		Last Day (Date of Stay)	70	137	46	77	409	70	214	119	101	999	70	6.06	2.7	1	14
Sheraton	Franchised	First Day	124	183	48	89	369	124	263	175	109	1999	124	4.20	1.95	1	15
		Last Day (Date of Stay)	120	177	45	89	359	120	264	181	109	1999	120	4.38	2.1	2	15
Westin	Franchised	First Day	39	226	74	129	495	39	391	209	179	1015	39	5.26	2.07	2	10
		Last Day (Date of Stay)	36	217	70	109	495	36	390	185	190	1015	36	6.14	2.24	2	13

Third Data Set			Min price					Max price					Number of prices offered				
Brand	Properties	Day	# Observations	Mean	Standard Deviation	Minimum	Maximum	# Observations	Mean	Standard Deviation	Minimum	Maximum	# Observations	Mean	Standard Deviation	Minimum	Maximum
Four Points	Chain Managed	First Day	5	132	44	75	185	5	226	97	135	380	5	15.00	3.00	12	19
		Last Day (Date of Stay)	5	136	33	95	185	5	177	33	135	225	5	15.00	4.10	12	22
Hyatt	Chain Managed	First Day	89	235	80	129	699	89	365	172	164	1119	89	14.00	6.05	1	30
		Last Day (Date of Stay)	90	217	69	79	509	90	336	160	79	925	90	13.21	5.75	3	30
Marriott	Chain Managed	First Day	148	225	60	79	449	148	360	221	139	1929	148	5.89	5.35	1	33
		Last Day (Date of Stay)	141	223	56	129	449	141	319	148	139	900	141	5.06	4.75	1	33
Radisson	Chain Managed	First Day	10	153	42	97	215	10	241	53	169	339	10	16.00	5.60	10	29
		Last Day (Date of Stay)	11	142	32	103	199	11	239	67	159	399	11	13.73	6.63	6	25
Sheraton	Chain Managed	First Day	46	200	55	109	359	46	342	139	169	833	46	12.54	6.00	4	36
		Last Day (Date of Stay)	46	189	52	109	355	46	296	134	144	799	46	11.59	5.00	7	30
Westin	Chain Managed	First Day	45	246	55	119	375	45	417	141	209	920	45	16.00	7.71	3	36
		Last Day (Date of Stay)	43	237	54	119	385	43	361	106	169	630	43	15.40	6.54	7	36
Four Points	Franchised	First Day	60	133	34	79	285	60	208	182	99	1500	60	11.33	5.12	4	25
		Last Day (Date of Stay)	58	184	76	85	195	58	184	76	85	560	58	10.95	4.81	4	25
Hyatt	Franchised	First Day	11	189	30	134	229	11	242	49	159	320	11	12.45	7.02	2	23
		Last Day (Date of Stay)	11	188	38.7	109	240	11	230	51	139	320	11	10.27	3.55	6	17
Marriott	Franchised	First Day	161	198	49	110	389	161	315	408	110	5039	161	5.35	6.71	1	78
		Last Day (Date of Stay)	166	200	46	100	359	166	289	231	139	2359	166	4.31	4.11	1	41
Radisson	Franchised	First Day	127	129	36	69	309	127	216	83	111	599	127	10.75	4.85	1	28
		Last Day (Date of Stay)	124	117	28	64	199	124	199	78	84	599	124	10.23	4.51	1	27
Sheraton	Franchised	First Day	123	165	44	83	349	123	259	82	145	560	123	11.04	4.39	2	30
		Last Day (Date of Stay)	120	162	40	89	269	120	238	83	105	570	120	8.86	3.27	4	18
Westin	Franchised	First Day	39	238	89	139	585	39	482	254	219	1230	39	13.74	6.3	4	36
		Last Day (Date of Stay)	39	218	85	125	646	39	474	365	194	2000	39	11.89	4.93	6	33

Table 3: Pairwise Correlations

Source: Smith Travel Research, property websites.

First Data Set	First Day								
	Chain managed indicator	Lowest price offered	Highest price offered	Number of prices offered	Rooms	Total meeting space	Distance to HQ	Vacation facilities indicator	Conference facilities indicator
Chain managed indicator	1.00								
Lowest price offered	0.32	1.00							
Highest price offered	0.21	0.51	1.00						
Number of prices offered	0.07	-0.03	0.42	1.00					
Rooms	0.46	0.32	0.25	0.17	1.00				
Total meeting space	0.31	0.15	0.12	0.11	0.68	1.00			
Distance to HQ	0.12	0.14	0.19	0.24	0.14	0.03	1.00		
Vacation facilities indicator	0.14	0.16	0.25	0.31	0.15	0.19	0.23	1.00	
Conference facilities indicator	0.42	0.21	0.13	0.09	0.59	0.52	0.13	0.22	1.00

	Last Day								
	Chain managed indicator	Lowest price offered	Highest price offered	Number of prices offered	Rooms	Total meeting space	Distance to HQ	Vacation facilities indicator	Conference facilities indicator
Chain managed indicator	1.00								
Lowest price offered	0.35	1.00							
Highest price offered	0.23	0.52	1.00						
Number of prices offered	0.13	-0.05	0.41	1.00					
Rooms	0.45	0.34	0.29	0.17	1.00				
Total meeting space	0.30	0.18	0.18	0.14	0.68	1.00			
Distance to HQ	0.08	0.07	0.18	0.24	0.13	0.02	1.00		
Vacation facilities indicator	0.14	0.12	0.25	0.31	0.16	0.22	0.22	1.00	
Conference facilities indicator	0.40	0.19	0.15	0.10	0.58	0.51	0.12	0.23	1.00

Second Data Set	First Day								
	Chain managed indicator	Lowest price offered	Highest price offered	Number of prices offered	Rooms	Total meeting space	Distance to HQ	Vacation facilities indicator	Conference facilities indicator
Chain managed indicator	1.00								
Lowest price offered	0.40	1.00							
Highest price offered	0.26	0.57	1.00						
Number of prices offered	0.08	-0.07	0.37	1.00					
Rooms	0.46	0.35	0.28	0.18	1.00				
Total meeting space	0.31	0.14	0.14	0.15	0.68	1.00			
Distance to HQ	0.08	0.06	0.17	0.22	0.13	0.03	1.00		
Vacation facilities indicator	0.15	0.16	0.35	0.37	0.17	0.24	0.21	1.00	
Conference facilities indicator	0.40	0.30	0.23	0.12	0.59	0.52	0.12	0.21	1.00

	Last Day								
	Chain managed indicator	Lowest price offered	Highest price offered	Number of prices offered	Rooms	Total meeting space	Distance to HQ	Vacation facilities indicator	Conference facilities indicator
Chain managed indicator	1.00								
Lowest price offered	0.38	1.00							
Highest price offered	0.23	0.52	1.00						
Number of prices offered	0.08	-0.10	0.34	1.00					
Rooms	0.46	0.27	0.21	0.21	1.00				
Total meeting space	0.30	0.10	0.10	0.18	0.71	1.00			
Distance to HQ	0.11	0.06	0.18	0.23	0.15	0.03	1.00		
Vacation facilities indicator	0.15	0.15	0.26	0.28	0.19	0.26	0.21	1.00	
Conference facilities indicator	0.41	0.27	0.20	0.15	0.58	0.53	0.14	0.24	1.00

Third Data Set	First Day								
	Chain managed indicator	Lowest price offered	Highest price offered	Number of prices offered	Rooms	Total meeting space	Distance to HQ	Vacation facilities indicator	Conference facilities indicator
Chain managed indicator	1.00								
Lowest price offered	0.40	1.00							
Highest price offered	0.17	0.49	1.00						
Number of prices offered	0.08	0.01	0.27	1.00					
Rooms	0.44	0.31	0.17	0.14	1.00				
Total meeting space	0.29	0.22	0.11	0.10	0.67	1.00			
Distance to HQ	0.09	0.14	0.16	0.17	0.13	0.03	1.00		
Vacation facilities indicator	0.15	0.29	0.39	0.23	0.18	0.24	0.21	1.00	
Conference facilities indicator	0.39	0.29	0.14	0.13	0.59	0.52	0.12	0.22	1.00

	Last Day								
	Chain managed indicator	Lowest price offered	Highest price offered	Number of prices offered	Rooms	Total meeting space	Distance to HQ	Vacation facilities indicator	Conference facilities indicator
Chain managed indicator	1.00								
Lowest price offered	0.39	1.00							
Highest price offered	0.18	0.59	1.00						
Number of prices offered	0.14	-0.04	0.26	1.00					
Rooms	0.44	0.32	0.21	0.17	1.00				
Total meeting space	0.29	0.22	0.14	0.13	0.67	1.00			
Distance to HQ	0.08	0.13	0.20	0.21	0.12	0.02	1.00		
Vacation facilities indicator	0.14	0.30	0.40	0.21	0.17	0.24	0.21	1.00	
Conference facilities indicator	0.38	0.30	0.20	0.18	0.59	0.52	0.12	0.22	1.00

Table 4: Regressions of price levels on franchise indicator on first and last days

	First Data Set		Second Data Set		Third Data Set	
VARIABLES	First Day lnminprice	Last Day lnminprice	First Day lnminprice	Last Day lnminprice	First Day lnminprice	Last Day lnminprice
Franchise indicator	-0.079***	-0.116***	-0.132***	-0.137***	-0.130***	-0.123***
	[0.025]	[0.027]	[0.029]	[0.026]	[0.025]	[0.025]
Hyatt	0.425***	0.409***	0.421***	0.436***	0.429***	0.438***
	[0.050]	[0.043]	[0.050]	[0.046]	[0.044]	[0.040]
Marriott	0.427***	0.521***	0.411***	0.464***	0.405***	0.492***
	[0.036]	[0.035]	[0.034]	[0.034]	[0.031]	[0.030]
Radisson	0.019	-0.004	0.008	0.052	-0.022	-0.034
	[0.035]	[0.044]	[0.035]	[0.051]	[0.035]	[0.032]
Sheraton	0.281***	0.308***	0.310***	0.305***	0.237***	0.292***
	[0.036]	[0.038]	[0.037]	[0.034]	[0.032]	[0.032]
Westin	0.522***	0.501***	0.528***	0.544***	0.530***	0.552***
	[0.050]	[0.044]	[0.047]	[0.048]	[0.043]	[0.043]
Constant	4.901***	4.848***	4.987***	4.971***	4.982***	4.896***
	[0.044]	[0.041]	[0.049]	[0.045]	[0.045]	[0.035]
Observations	827	761	860	739	864	854
R-squared	0.355	0.414	0.395	0.382	0.420	0.498

Robust standard errors in brackets, clustered at the str market level
*** p<0.01, ** p<0.05, * p<0.1
Omitted brand is Four Points

Table 5: Price trends and organizational form

VARIABLES	1st Data Set lnminprice	2nd Data Set lnminprice	3rd Data Set lnminprice	1st Data Set lnmaxprice	2nd Data Set lnmaxprice	3rd Data Set lnmaxprice	1st Data Set lnpricecount	2nd Data Set lnpricecount	3rd Data Set lnpricecount	1st Data Set Pr(change in min price)	2nd Data Set Pr(change in min price)	3rd Data Set Pr(change in min price)
dayspassed	-0.007	0.193***	-0.044***	-0.086***	0.068	-0.175***	-0.131***	-0.546***	-0.149***			
	[0.020]	[0.044]	[0.014]	[0.020]	[0.062]	[0.016]	[0.039]	[0.123]	[0.032]			
franchise_dayspassed	-0.139***	-0.120**	-0.038**	-0.020	-0.061	0.012	-0.043	0.196	-0.182***	-0.007	0.050***	-0.034
	[0.027]	[0.052]	[0.018]	[0.028]	[0.072]	[0.022]	[0.053]	[0.154]	[0.042]	[0.009]	[0.014]	[0.028]
franchise										0.109	-0.430***	0.734
										[0.185]	[0.118]	[0.777]
Constant	519***	521***	517***	559***	558***	561***	150***	149***	212***			
	[0.236]	[0.165]	[0.204]	[0.241]	[0.216]	[0.251]	[0.478]	[0.505]	[0.472]			
Observations	18640	11444	37052	18640	11444	37052	18640	11444	37052	13876	9548	627
R-squared	0.944	0.976	0.950	0.949	0.966	0.951	0.910	0.901	0.928			

Robust standard errors in brackets, clustered at property-week level for first three dependent variables and at dayspassed level for last dependent variable

*** p<0.01, ** p<0.05, * p<0.1

Table 6: Controlling for alternative property-level explanations

Panel A

	First Data Set					Second Data Set					Third Data set				
VARIABLES	lnminprice	lnminprice	lnminprice	lnminprice	lnminprice	lnminprice	lnminprice	lnminprice	lnminprice	lnminprice	lnminprice	lnminprice	lnminprice	lnminprice	lnminprice
dayspassed	-0.066*	-0.038	-0.034	0.012	0.024	0.180**	0.199***	0.209***	0.198***	0.219***	-0.032	-0.042**	-0.037**	-0.042***	-0.043**
	[0.035]	[0.024]	[0.025]	[0.022]	[0.026]	[0.087]	[0.049]	[0.057]	[0.049]	[0.057]	[0.023]	[0.016]	[0.018]	[0.015]	[0.018]
franchise_dayspassed	-0.112***	-0.125***	-0.122***	-0.150***	-0.143***	-0.114*	-0.129**	-0.130**	-0.123**	-0.124**	-0.044**	-0.037*	-0.043**	-0.039**	-0.038**
	[0.029]	[0.027]	[0.028]	[0.027]	[0.026]	[0.060]	[0.053]	[0.058]	[0.055]	[0.052]	[0.020]	[0.019]	[0.020]	[0.018]	[0.018]
rooms_dayspassed	0.000*					0.000					-0.000				
	[0.000]					[0.000]					[0.000]				
meeting_dayspassed		0.000**					-0.000					-0.000			
		[0.000]					[0.000]					[0.000]			
confac_dayspassed			0.047*					-0.026					-0.012		
			[0.028]					[0.057]					[0.020]		
vacfac_dayspassed				-0.143**					-0.030					-0.013	
				[0.056]					[0.096]					[0.032]	
distHQ_dayspassed					-0.000*					-0.000					-0.000
					[0.000]					[0.000]					[0.000]
Constant	520***	520***	520***	520***	520***	522***	522***	522***	522***	522***	518***	518***	518***	518***	518***
	[0.236]	[0.236]	[0.236]	[0.236]	[0.236]	[0.165]	[0.164]	[0.165]	[0.165]	[0.164]	[0.204]	[0.204]	[0.204]	[0.204]	[0.204]
Observations	18640	18592	18640	18640	18640	11444	11402	11444	11444	11444	37052	36880	37052	37052	37052
R-squared	0.944	0.944	0.944	0.944	0.944	0.976	0.976	0.976	0.976	0.976	0.950	0.950	0.950	0.950	0.950

Robust standard errors in brackets, clustered at property-week level
*** p<0.01, ** p<0.05, * p<0.1

Panel B

	First Data Set					Second Data Set					Third Data set				
VARIABLES	lnminprice	lnminprice	lnminprice	lnminprice	lnminprice	lnminprice	lnminprice	lnminprice	lnminprice	lnminprice	lnminprice	lnminprice	lnminprice	lnminprice	lnminprice
dayspassed	-0.047	-0.000	-0.022	0.004	0.032	0.192*	0.206***	0.198***	0.205***	0.219***	0.000	-0.039**	-0.011	-0.043***	-0.036*
	[0.039]	[0.024]	[0.030]	[0.022]	[0.028]	[0.106]	[0.052]	[0.072]	[0.050]	[0.070]	[0.025]	[0.017]	[0.021]	[0.015]	[0.021]
franchise_dayspassed	-0.169***	-0.226***	-0.138***	-0.136***	-0.162***	-0.145	-0.147**	-0.116	-0.134**	-0.124	-0.134***	-0.045**	-0.078***	-0.038**	-0.053*
	[0.051]	[0.034]	[0.036]	[0.028]	[0.041]	[0.121]	[0.061]	[0.077]	[0.056]	[0.082]	[0.036]	[0.023]	[0.025]	[0.019]	[0.027]
rooms_dayspassed	0.000					0.000					-0.000**				
	[0.000]					[0.000]					[0.000]				
franchise_rooms_dayspassed	0.000					0.000					0.000***				
	[0.000]					[0.000]					[0.000]				
meeting_dayspassed		-0.000					-0.000					-0.000			
		[0.000]					[0.000]					[0.000]			
franchise_meeting_dayspassed		0.000***					0.000					0.000			
		[0.000]					[0.000]					[0.000]			
confac_dayspassed			0.027					-0.008					-0.058**		
			[0.041]					[0.091]					[0.028]		
franchise_con_dayspassed			0.042					-0.034					0.092**		
			[0.057]					[0.115]					[0.040]		
vacfac_dayspassed				-0.081					-0.082					-0.007	
				[0.058]					[0.087]					[0.043]	
franchise_vac_dayspassed				-0.154					0.129					-0.017	
				[0.123]					[0.218]					[0.063]	
distHQ_dayspassed					-0.000*					-0.000					-0.000
					[0.000]					[0.000]					[0.000]
franchise_distHQ_dayspassed					0.000					-0.000					0.000
					[0.000]					[0.000]					[0.000]
Constant	519***	519***	519***	519***	519***	521***	521***	521***	521***	521***	518***	518***	518***	518***	518***
	[0.236]	[0.235]	[0.236]	[0.235]	[0.236]	[0.165]	[0.164]	[0.165]	[0.165]	[0.164]	[0.204]	[0.204]	[0.204]	[0.204]	[0.204]
Observations	18640	18592	18640	18640	18640	11444	11402	11444	11444	11444	37052	36880	37052	37052	37052
R-squared	0.944	0.944	0.944	0.944	0.944	0.976	0.976	0.976	0.976	0.976	0.950	0.950	0.950	0.950	0.950

Robust standard errors in brackets, clustered at property-week level
*** p<0.01, ** p<0.05, * p<0.1

Table 7: Controlling for alternative market-level explanations

	First Data Set			Second Data Set			Third Data Set		
VARIABLES	lnminprice	lnminprice	lnminprice	lnminprice	lnminprice	lnminprice	lnminprice	lnminprice	lnminprice
dayspassed	0.097***	-0.048**	-0.013	0.205***	0.224***	0.158***	-0.010	-0.064***	-0.055***
	[0.029]	[0.023]	[0.024]	[0.059]	[0.049]	[0.049]	[0.020]	[0.016]	[0.017]
franchise_dayspassed	-0.172***	-0.160***	-0.145***	-0.123**	-0.106**	-0.114**	-0.048**	-0.048***	-0.043**
	[0.028]	[0.027]	[0.027]	[0.053]	[0.052]	[0.052]	[0.019]	[0.019]	[0.018]
marketN_dayspassed	-0.006***			-0.001			-0.002**		
	[0.001]			[0.002]			[0.001]		
marketHHI_dayspassed		0.295***			-0.225			0.153***	
		[0.069]			[0.142]			[0.053]	
normmarketHHI_dayspassed			0.211			1.203*			0.451
			[0.390]			[0.680]			[0.308]
Constant	520***	520***	520***	522***	522***	522***	518***	518***	518***
	[0.235]	[0.235]	[0.239]	[0.165]	[0.164]	[0.166]	[0.204]	[0.204]	[0.206]
Observations	18640	18640	18294	11444	11444	11232	37052	37052	36334
R-squared	0.945	0.944	0.944	0.976	0.976	0.976	0.950	0.950	0.949

Robust standard errors in brackets, clustered at property-week level
*** p<0.01, ** p<0.05, * p<0.1

	First Data Set			Second Data Set			Third Data Set		
VARIABLES	lnminprice	lnminprice	lnminprice	lnminprice	lnminprice	lnminprice	lnminprice	lnminprice	lnminprice
dayspassed	0.011	0.011	0.033	0.221***	0.216***	0.213***	-0.086***	-0.048**	-0.027
	[0.034]	[0.028]	[0.029]	[0.076]	[0.058]	[0.063]	[0.025]	[0.020]	[0.021]
franchise_dayspassed	-0.024	-0.252***	-0.209***	-0.149*	-0.094	-0.186**	0.074**	-0.074***	-0.082***
	[0.042]	[0.038]	[0.036]	[0.085]	[0.073]	[0.073]	[0.031]	[0.026]	[0.026]
marketN_dayspassed	-0.001			-0.002			0.002**		
	[0.002]			[0.003]			[0.001]		
franchise_marketN_dayspassed	-0.010***			0.002			-0.008***		
	[0.002]			[0.004]			[0.002]		
marketHHI_dayspassed		-0.129			-0.168			0.029	
		[0.119]			[0.243]			[0.114]	
franchise_marketHHI_dayspassed		0.586***			-0.077			0.171	
		[0.145]			[0.298]			[0.128]	
normmarketHHI_dayspassed			-1.294**			-0.773			-0.569
			[0.610]			[1.497]			[0.494]
franchise_nmarketHHI_dayspassed			2.039***			2.494			1.378**
			[0.770]			[1.675]			[0.623]
Constant	520***	520***	520***	522***	522***	522***	518***	518***	518***
	[0.235]	[0.235]	[0.239]	[0.165]	[0.165]	[0.165]	[0.203]	[0.203]	[0.206]
Observations	18640	18640	18294	11444	11444	11232	37052	37052	36334
R-squared	0.945	0.945	0.944	0.976	0.976	0.976	0.951	0.950	0.950

Robust standard errors in brackets, clustered at property-week level
*** p<0.01, ** p<0.05, * p<0.1

Table 8: Cross market variations in relative price trends

Panel A

	First Data Set					Second Data Set					Third Data Set				
VARIABLES	lnminprice	lnminprice	lnminprice	lnminprice	lnminprice	lnminprice	lnminprice	lnminprice	lnminprice	lnminprice	lnminprice	lnminprice	lnminprice	lnminprice	lnminprice
dayspassed	0.178**	0.149**	0.291***	0.173**	0.227***	0.270**	0.278**	0.314**	0.239**	0.234*	0.006	-0.008	0.054	-0.009	-0.007
	[0.073]	[0.068]	[0.074]	[0.075]	[0.071]	[0.118]	[0.136]	[0.130]	[0.120]	[0.141]	[0.045]	[0.047]	[0.046]	[0.046]	[0.049]
franchise_dayspassed	-0.302***	-0.281***	-0.362***	-0.310***	-0.283***	-0.235*	-0.241*	-0.259**	-0.239*	-0.219*	-0.101**	-0.091*	-0.125***	-0.105**	-0.078
	[0.075]	[0.071]	[0.075]	[0.076]	[0.070]	[0.123]	[0.133]	[0.128]	[0.124]	[0.133]	[0.047]	[0.047]	[0.047]	[0.047]	[0.048]
sharechainmanaged_dayspassed	-0.241***	-0.234***	-0.252***	-0.243***	-0.207**	-0.102	-0.106	-0.110	-0.114	-0.090	-0.066	-0.061	-0.072	-0.061	-0.033
	[0.090]	[0.088]	[0.090]	[0.091]	[0.087]	[0.164]	[0.167]	[0.165]	[0.167]	[0.169]	[0.057]	[0.056]	[0.057]	[0.057]	[0.057]
franchise_sharechainmanaged_dayspassed	0.112	0.069	0.231*	0.127	0.072	0.347*	0.359	0.396*	0.354*	0.315	0.146*	0.126	0.194***	0.152**	0.100
	[0.116]	[0.112]	[0.118]	[0.117]	[0.112]	[0.197]	[0.222]	[0.208]	[0.199]	[0.222]	[0.075]	[0.078]	[0.075]	[0.076]	[0.078]
marketchainN_dayspassed		0.000			0.001***		-0.000			0.001		0.000			0.000***
		[0.000]			[0.000]		[0.001]			[0.001]		[0.000]			[0.000]
marketN_dayspassed			-0.006***		-0.013***			-0.002		-0.003			-0.002***		-0.005***
			[0.001]		[0.002]			[0.002]		[0.003]			[0.001]		[0.001]
normmarketHHI_dayspassed				0.189	-0.337				1.342**	1.217*				0.490	0.236
				[0.394]	[0.406]				[0.680]	[0.700]				[0.311]	[0.319]
Constant	520***	520***	520***	520***	520***	522***	522***	522***	522***	522***	518***	518***	518***	518***	518***
	[0.235]	[0.235]	[0.234]	[0.238]	[0.236]	[0.164]	[0.164]	[0.164]	[0.165]	[0.165]	[0.204]	[0.204]	[0.203]	[0.206]	[0.205]
Observations	18640	18640	18640	18294	18294	11444	11444	11444	11232	11232	37052	37052	37052	36334	36334
R-squared	0.944	0.944	0.945	0.944	0.945	0.976	0.976	0.976	0.976	0.976	0.950	0.950	0.951	0.950	0.950

Robust standard errors in brackets, clustered at property-week level
*** p<0.01, ** p<0.05, * p<0.1

Panel B

	First Data Set					Second Data Set					Third Data Set				
VARIABLES	lnminprice	lnminprice	lnminprice	lnminprice	lnminprice	lnminprice	lnminprice	lnminprice	lnminprice	lnminprice	lnminprice	lnminprice	lnminprice	lnminprice	lnminprice
dayspassed	-0.097***	-0.080***	0.020	-0.109***	0.022	0.186***	0.180***	0.221***	0.138**	0.155**	-0.080***	-0.091***	-0.041*	-0.093***	-0.061**
	[0.029]	[0.031]	[0.033]	[0.032]	[0.038]	[0.060]	[0.068]	[0.069]	[0.066]	[0.079]	[0.019]	[0.022]	[0.024]	[0.021]	[0.028]
franchise_dayspassed	-0.013	-0.032	-0.096**	-0.026	-0.066	-0.162**	-0.155*	-0.192**	-0.159**	-0.157*	0.021	0.033	-0.014	0.009	-0.002
	[0.040]	[0.041]	[0.041]	[0.040]	[0.042]	[0.077]	[0.086]	[0.083]	[0.078]	[0.088]	[0.029]	[0.032]	[0.032]	[0.030]	[0.033]
Nfranchise_dayspassed	0.003***	0.003***	0.004***	0.003***	0.003***	0.000	0.000	0.001	0.001	-0.000	0.001***	0.001**	0.001***	0.001***	0.000*
	[0.001]	[0.001]	[0.001]	[0.001]	[0.001]	[0.002]	[0.002]	[0.002]	[0.002]	[0.002]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]
franchise_Nfranchise_dayspassed	-0.004***	-0.004***	-0.003***	-0.004***	-0.003***	0.001	0.001	0.002	0.001	0.002	-0.001***	-0.001***	-0.001**	-0.001***	-0.001*
	[0.001]	[0.001]	[0.001]	[0.001]	[0.001]	[0.002]	[0.002]	[0.002]	[0.002]	[0.002]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]
marketchainN_dayspassed		-0.000			0.001***		0.000			0.001		0.000			0.000***
		[0.000]			[0.000]		[0.001]			[0.001]		[0.000]			[0.000]
marketN_dayspassed			-0.008***		-0.012***			-0.002		-0.004			-0.003***		-0.005***
			[0.001]		[0.002]			[0.003]		[0.003]			[0.001]		[0.001]
normmarketHHI_dayspassed				0.308	-0.359				1.430**	1.289*				0.468	0.228
				[0.387]	[0.403]				[0.697]	[0.703]				[0.311]	[0.318]
Constant	520***	520***	520***	520***	520***	522***	522***	522***	522***	522***	518***	518***	518***	518***	518***
	[0.234]	[0.233]	[0.231]	[0.237]	[0.234]	[0.165]	[0.165]	[0.165]	[0.166]	[0.165]	[0.204]	[0.204]	[0.203]	[0.206]	[0.205]
Observations	18640	18640	18640	18294	18294	11444	11444	11444	11232	11232	37052	37052	37052	36334	36334
R-squared	0.945	0.945	0.945	0.944	0.945	0.976	0.976	0.976	0.976	0.976	0.950	0.950	0.951	0.950	0.950

Robust standard errors in brackets, clustered at property-week level
*** p<0.01, ** p<0.05, * p<0.1

Figure 1: Average Price Levels

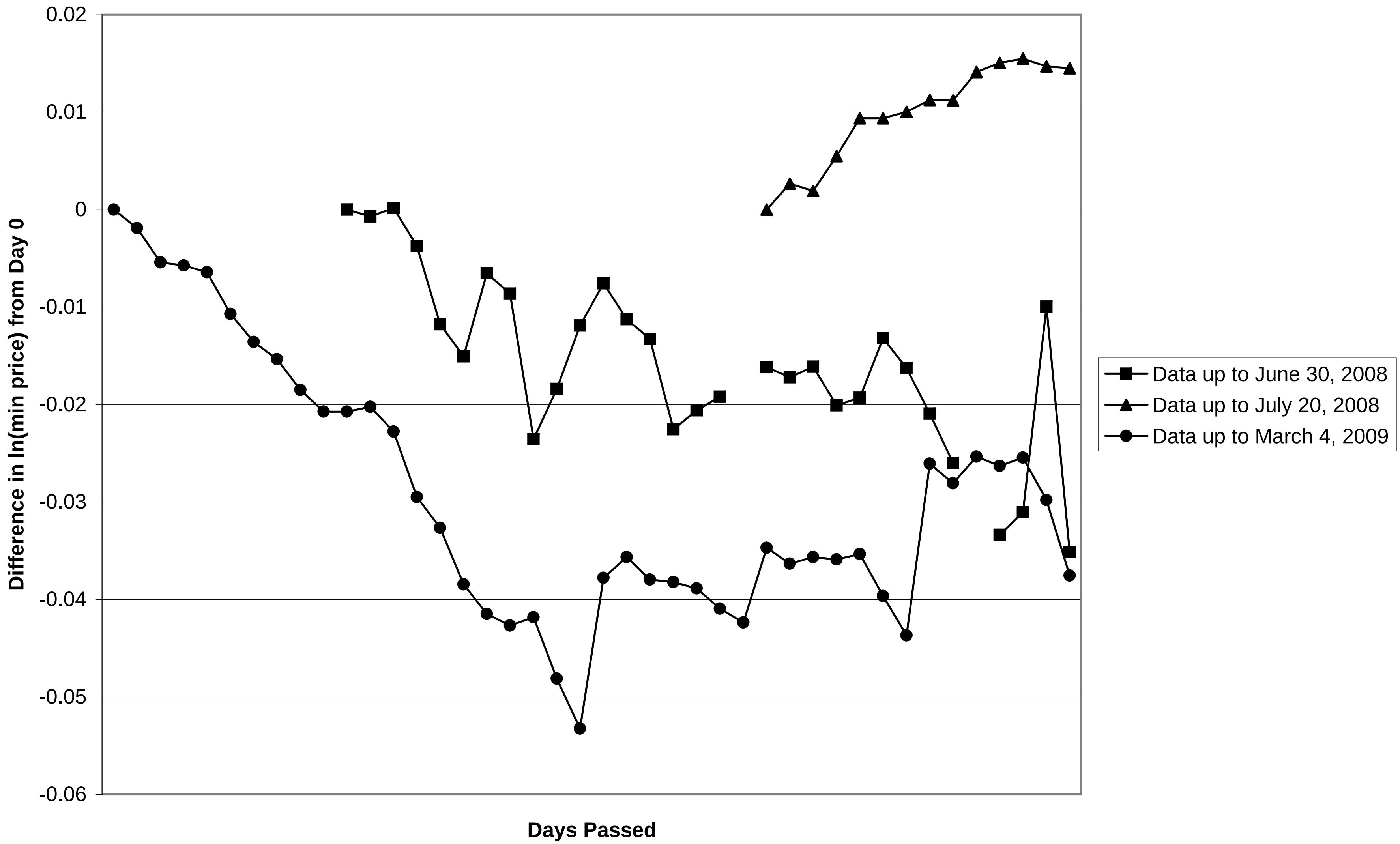

Figure 2: First Data Set

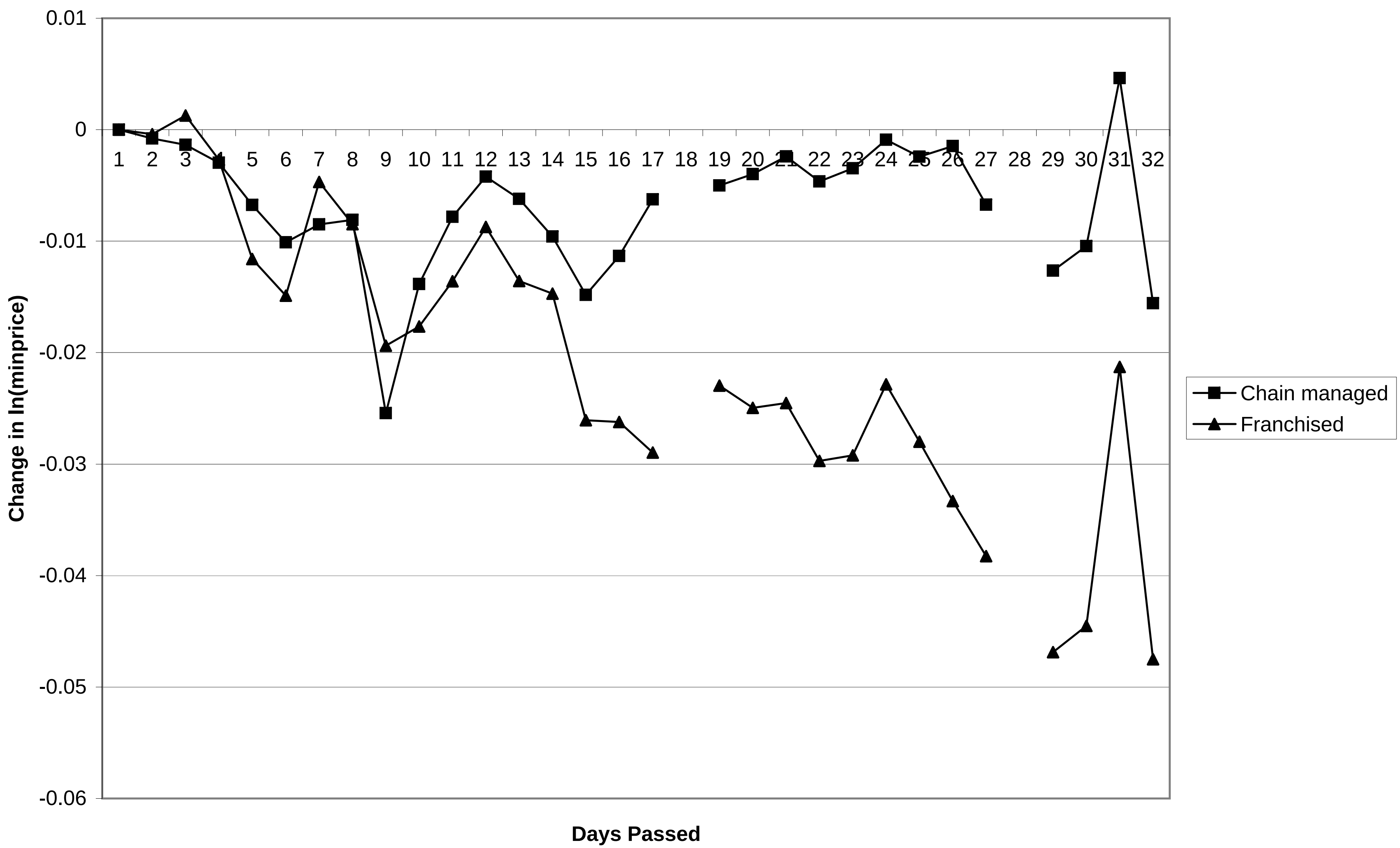

Figure 3: Second Data Set

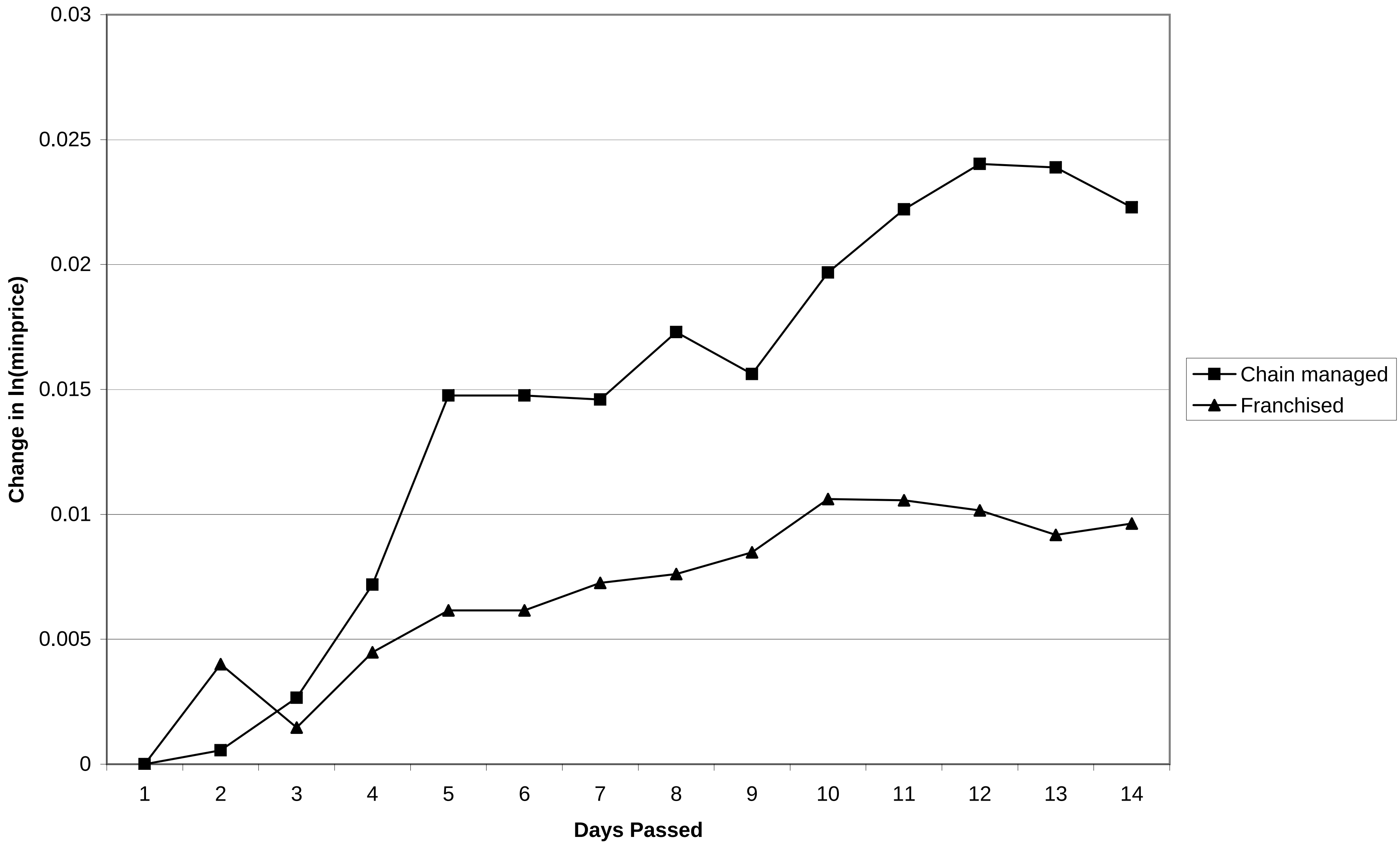

Figure 4: Third Data Set

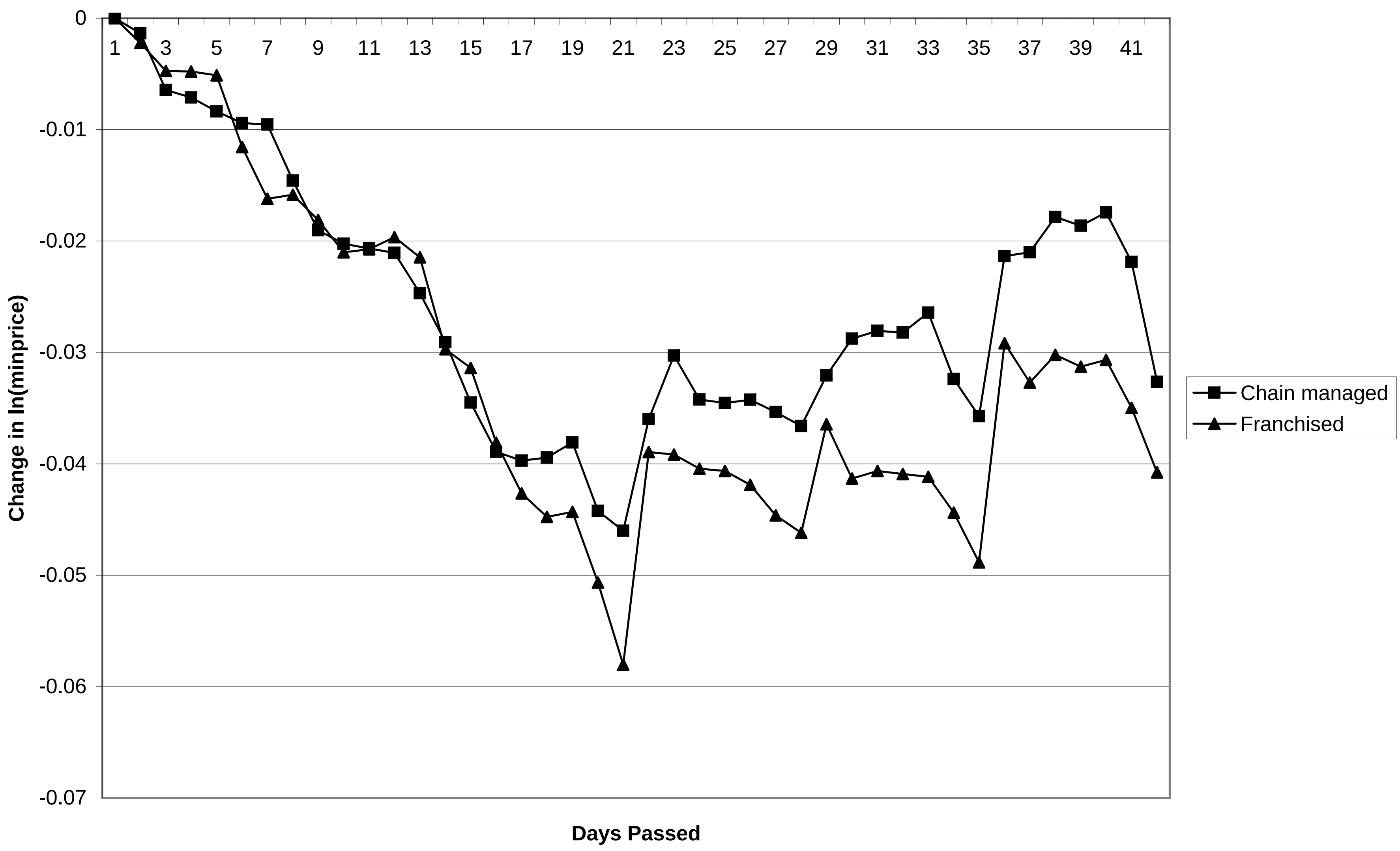

Figure 5: Relative Price Levels

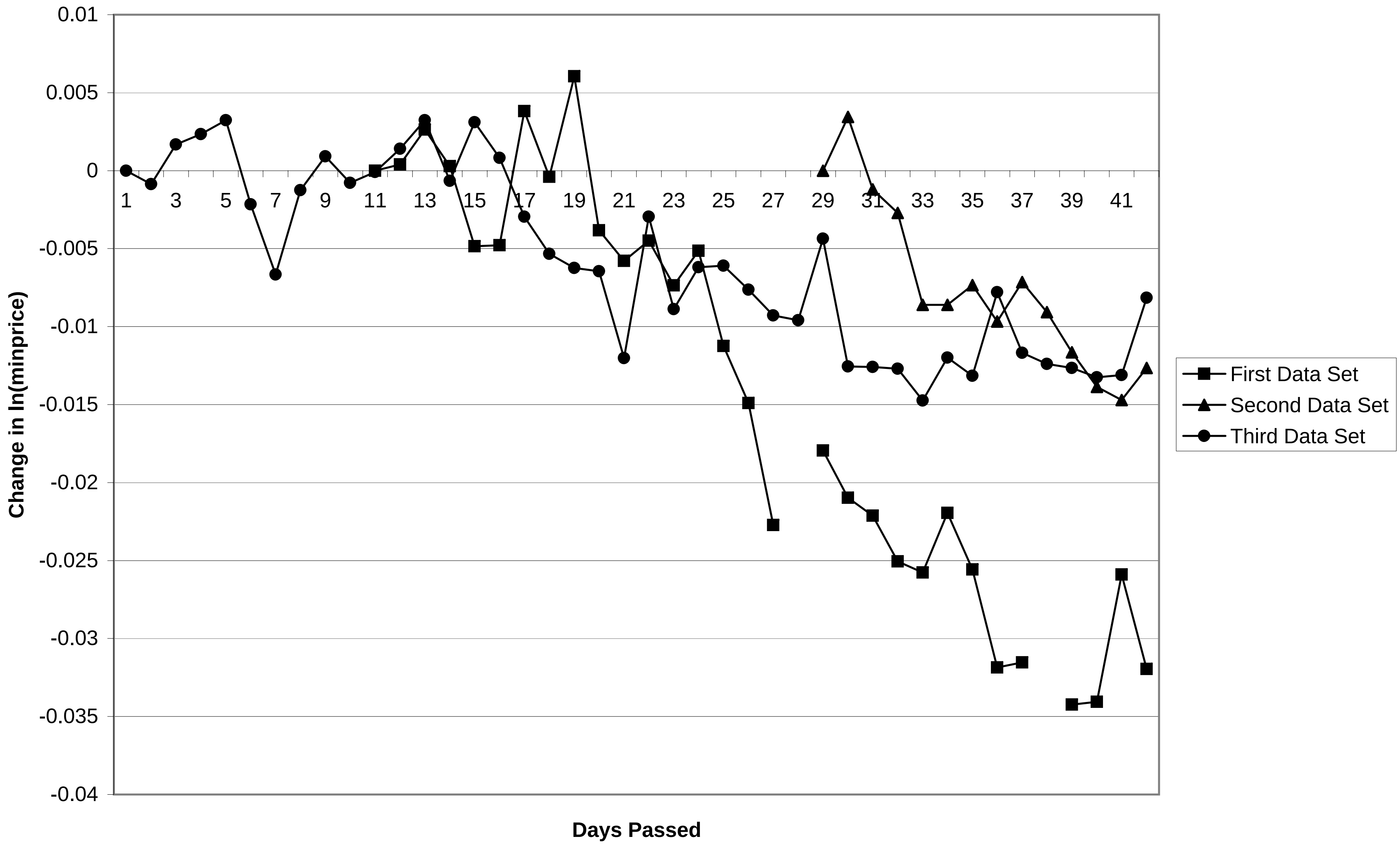

Figure 6: Two hotels with Uncertainty (model in main text)

Notes: In figures 6 to 10, non-shaded areas represent values of b and c where the franchised hotel cuts prices by more than the chain managed hotel(s) in the second period. Values for b are given on the x-axis and values for c are given on the y-axis.

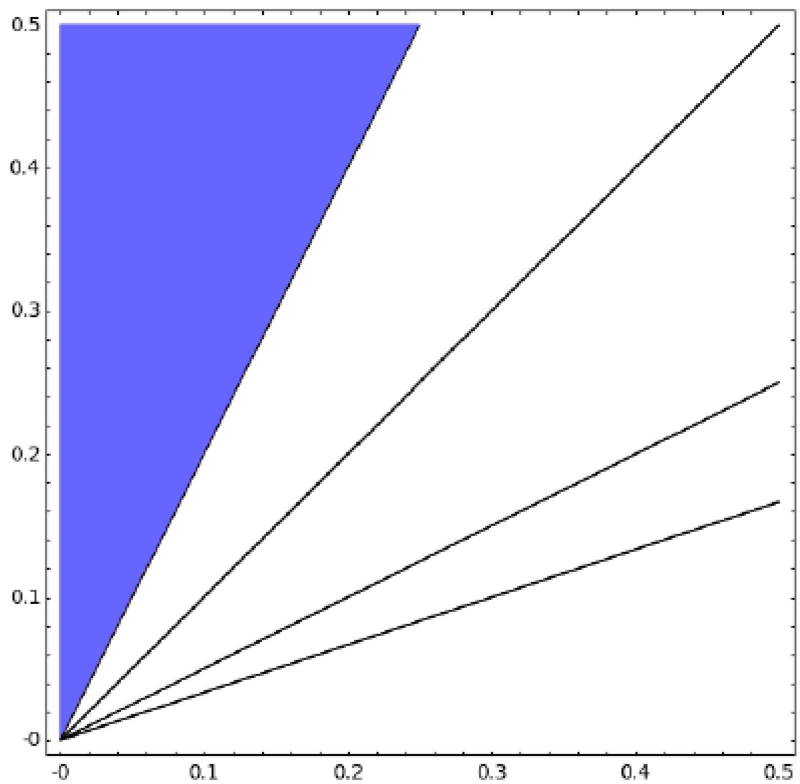

Figure 7: Three hotel case with no uncertainty (first case in the appendix)

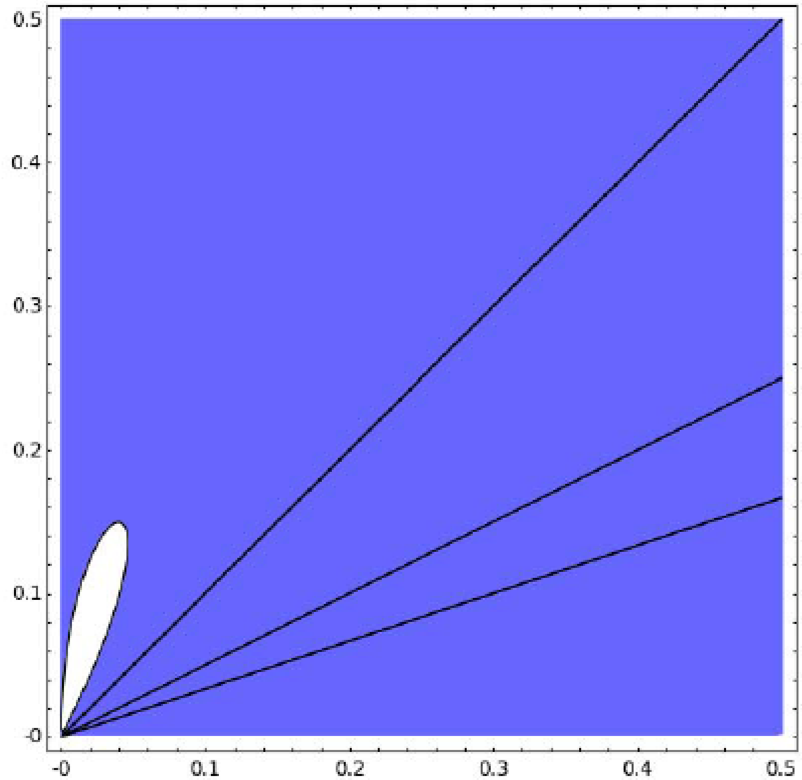

Figure 8: Three hotel case with uncertainty, second case in the appendix , lhs=0.1

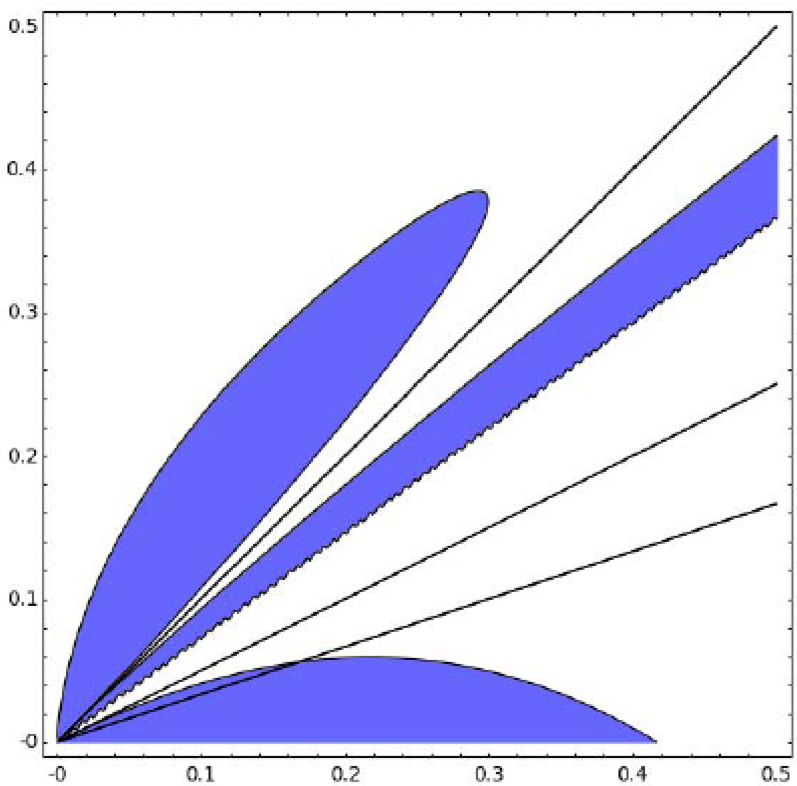

Figure 9: Three hotel case with uncertainty, second case in the appendix, lhs=0.2

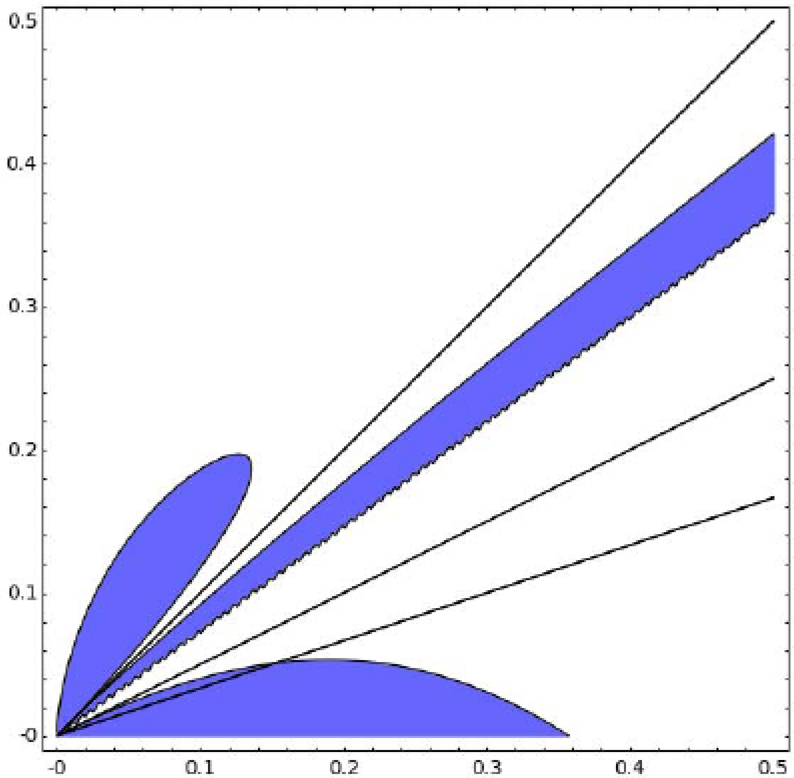

Figure 10: Three hotel case with uncertainty, second case in the appendix, lhs=0.3