Market concentration and price dispersion; the role of asymmetric spatial competition

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Economic literature on the impact of competition on price dispersion in civil aviation yields ambiguous results. We show that asymmetric spatial competition drives both interfirm price dispersion and market share inequality.

We apply our framework to a panel data set of long haul and short haul air markets originating in Europe. We decompose the Hirschmann Herfindahl index in our analysis and find that price dispersion is related to market share inequality rather than market concentration. This confirms our theoretical finding that both price dispersion and market share inequality are caused by (unobserved) product differentiation. Moreover, our results are also consistent with PED-type models of price dispersion.

Keywords: Price dispersion; civil aviation; Europe; spatial competition; product differentiation

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1 Introduction

The issue of price dispersion has drawn considerable attention from economic academics in the last decades. Why do prices differ between essentially the same products? Why are passengers willing to pay these prices? Two obvious candidates for explaining the difference have been shown to be unable to tell the full story. Dana (1999) formalizes Prescott’s (1975) model of price dispersion and finds that demand uncertainty and fixed costs can explain the existence of intrafirm price dispersion in competitive and oligopoly markets, but not interfirm price dispersion. The other obvious candidate would be search cost differences between consumers. Theoretically, search costs allow firms to set higher prices than their competitors, as consumers that are not aware of alternatives may not switch. Orlov (2011) finds that increases in internet penetration do affect price levels and intrafirm price dispersion, but not interfirm price dispersion, suggesting that consumer search costs are not the (only) answer.

We explore the possibility that interfirm price dispersion reveals the presence of unobserved product differentiation. We show that an increase in the asymmetry in product differentiation leads to interfirm price dispersion as well as market share inequality. Since the commonly used Hirschmann Herfindahl Index (HHI) is also affected by market share inequality, we argue that it does not correctly reflect the impact of competition on price dispersion. Instead, we propose to decompose the index into the inverse number of competitors and the market share inequality.

Civil aviation is one of the sectors where price dispersion is clearly present. Moreover, this sector is well documented and price information can be made available relatively easy. It comes as no surprise therefore, that aviation is the scene of many empirical studies on price dispersion. With basic price discrimination theory in mind, the level competition is an obvious candidate for explaining price dispersion in the airline industry. A mixed image of the impact of competition on price dispersion arises from recent literature. Borenstein & Rose (1994); Hayes & Ross (1998); Giaume and Guillou (2004) and Bilotkach (2006) find a positive relationship between the level of competition and price dispersion, whereas Evans et al. (1993) and Gerardi and Shapiro (2009) find a negative relationship. Orlov (2011) finds an indirect relationship through lower search costs, causing both lower price levels and a higher level of intrafirm price dispersion, but no effect on interfirm price dispersion. Both Carlsson (2004) and Mantin and Koo (2009) find no relationship between competition and price dispersion, whereas, Dai et al. (2010) find the relationship to be parabolic.

This raises the question what the real impact of competition on price dispersion is. Could it be positive for some markets and negative for others? Is the relationship merely incidental or can we pinpoint factors that influence the relationship? The clue lies in clearly distinguishing between price discrimination and intrafirm price dispersion, as brought forward by Dana (1999). In many of the existing
studies, this distinction is implicit. Moreover, airline fare structures use complex advanced second degree price discrimination, defining sets of rules in order to have travelers self select the most appropriate price, as Borenstein and Rose (1994) state. Some of those rules, especially the ones relating to flexibility, are on, or even over, the threshold of product diversification rather than price discrimination.

Our contribution to the literature is twofold. First, we explicitly focus on interfirm price dispersion only and develop a theoretical framework for it. Existing theoretical frameworks so far have only managed to explain intrafirm price discrimination. Second, we use a decomposed version of the HHI (see Hannan (1997), to be able to distinguish between the effect of the number of competitors and the effect of market share inequalities on price dispersion.

The remainder of the paper is organized as follows. Section 2 sets out to describe the base model used in our analysis, followed by an analysis of the consequences of asymmetric spatial competition in our model. Section 4 translates our theoretical framework to an empirically testable specification. The data and empirical results are discussed in section 5 and conclusions are provided in section 6.

2 The model

The basic model closely follows the lines of the pricing stage in a Hotelling type spatial competition model with a uniform distribution and quadratic transportation costs. Similar models can be found in nearly any textbook of industrial organization. Firms 1 and 2 are located at positions $a$ and $1-b$ respectively in a linear market and compete in prices. Without loss of generality, we assume that $1-a-b\geq0$, so that firm 1 is located to the left of firm 2. If $a+b=1$, the products of firms 1 and 2 are perfect substitutes (minimum differentiation), whereas maximum differentiation is denoted by $a=b=0$.

Consumers are assumed to be uniformly distributed over the interval $[0,1]$ with density 1. Every consumer buys one unit of output from one of the firms and choose the firm from which to buy form based on the mill price and transport costs. The consumer who is indifferent between firm 1 and firm 2 is located at $x$, such that:

$$p_1 + t \cdot x-a^2 = p_2 + t \cdot 1-b-x^2$$  \hspace{1cm} (1)

Where $p_i$ denotes the mill price set by firm i. All consumers to the left of the indifferent consumer will buy from firm 1 and all consumers to the right will buy from firm 2. It is straightforward to obtain firms’ demands:

$$D_1 = x = a + \frac{1-a-b}{2} + \frac{p_2 - p_1}{2t(1-a-b)}$$  \hspace{1cm} (2)

---

1 We adopt the notation used by Tirole, 1997.
\begin{equation}
D_2 = 1 - x = b + \frac{1-a-b}{2} + \frac{p_1 - p_2}{2t(1-a-b)}
\end{equation}

Firms maximize profits, defined as \((p_r-c)D\), in a Bertrand-Nash game. It can be checked that the Nash equilibrium exists, yielding prices:

\begin{equation}
p_1^N = c + t(1-a-b)\left(1 + \frac{a-b}{3}\right)
\end{equation}

And

\begin{equation}
p_2^N = c + t(1-a-b)\left(1 + \frac{b-a}{3}\right)
\end{equation}

Substituting equilibrium prices into (2) and (3) yields after some simplification:

\begin{equation}
D_1^N = a + \frac{1-a-b}{2} + \frac{b-a}{3}
\end{equation}

\begin{equation}
D_2^N = b + \frac{1-a-b}{2} + \frac{a-b}{3}
\end{equation}

For later use in our empirical analysis, we define a measure for market share inequality based on the Hirschmann Herfindahl Index (HHI). The HHI is a commonly used measure of market concentration, which is defined as the sum of the market squares of all firms. It takes into account both the number of firms and their market share inequality. Since we are mainly interested in the latter here, we follow Hannan’s (1997) decomposition of the HHI, and define:

\begin{equation}
\frac{\sqrt{V}}{N} = HHI - \frac{1}{N}
\end{equation}

With \(V\) denoting the coefficient of variation of the outputs of the firms in the market. Since the HHI is defined as the sum of squared market shares and total demand in our theoretical model is set equal to one, we find:

\begin{equation}
\frac{\sqrt{V}}{N} = \frac{1}{2} + 2D_1^2 - 2D_1
\end{equation}

This measure of market share inequality is zero for equal market shares \((D_1 = D_2 = \frac{1}{2})\) and has an upper bound in \(\frac{1}{2}\) (entire market goes to either firm).
3. Asymmetry in product differentiation

In the following analysis, we will focus on the impact of asymmetry in product differentiation. Asymmetry in spatial competition occurs if \( a \neq b \). Although our analysis does not take the location stage of the Hotelling game into consideration, we note that asymmetric location choice in spatial competition is a fairly common phenomenon. Asymmetric outcomes of the location stage occur in the case of sequential entry and in the case of alternative underlying distributions of consumer preferences. Restrictions, such as capacity limits or zoning laws, may also affect location patterns, leading to asymmetry in product differentiation. In the case of airlines, one can also think of other reasons, such as departure timing depending on departure times of connecting flights or the value of an FFP depending on the network of the airline and its partners.

We distinguish between the level of product differentiation, as defined by the distance between the firms’ location \((1-a-b)\) and the asymmetry of product differentiation, as measured by the difference between \(a\) and \(b\). Note that these measures are independent of each other. Firms can have identical products but be located far from the centre of the market, or have highly differentiated products at symmetric locations. We therefore conjecture that

\[
\frac{\partial(1-a-b)}{\partial b-a} = 0
\]

**Proposition 1.** If products are differentiated and transport costs are strictly positive, interfirm price dispersion increases with asymmetry in locations.

**Proof.** Price dispersion in a duopoly is equivalent to the difference in prices. Subtracting (5) from (4) yields:

\[
p_1^N - p_2^N = 2t(1-a-b)\left(\frac{a-b}{3}\right)
\]

(9)

If products are perfectly homogeneous, \(1-a-b=0\); and price dispersion would be absent, as would be the case for zero transport costs. Differentiating (9) with respect to \((a-b)\) yields:

\[
\frac{\partial p_1^N - p_2^N}{\partial a-b} = \frac{2}{3}t(1-a-b) \geq 0
\]

(10)

Which is strictly positive for \(t>0; 1-a-b>0\).

QED

**Proposition 2.** Market share inequality increases with asymmetry in locations.
Proof. We start by assessing the situation where locations are symmetric, i.e. \( a = b \). It can be checked from (6) through (8) that market share inequality equals zero, whereas it is exceeds zero for any \( a \neq b \).

For \( a \neq b \), we differentiate equation (8) with respect to \((a-b)\):

\[
\frac{\partial}{\partial \ a-b} \frac{V^2}{N} = 4D_1 - 2 \frac{\partial D_1}{\partial \ a-b}
\]  

Differentiating (6) with respect to \((a-b)\) yields:

\[
\frac{\partial D_1}{\partial \ a-b} = \frac{1}{6} > 0
\]

We distinguish between two different cases, i.e. \( a > b \) and \( a < b \). From (6) we have that \( a > b \) implies \( D_1 > \frac{1}{6} \) and hence (11) is strictly positive. Similarly, for \( a < b \), (11) is strictly negative, but the interpretation changes as well, since an increase in \( a - b \) implies a decrease in asymmetry if \( a < b \). Hence we still have that market share inequality increases with asymmetry in locations.

QED

From propositions 1 and 2 we have that any deviation from \( a=b \) leads to an increase in both price dispersion and market share inequality. This implies that we would expect price dispersion and market share inequality to be positively related.

4 Empirical specification

We have shown in the previous section that the relationship between market concentration and price dispersion may run through unobserved asymmetry in product differentiation. As asymmetry in production differentiation can't be measured directly, we focus in the relationship between price dispersion and market share inequality. Before turning to the functional form of the equation to be estimated, we discuss our measure for interfirm price dispersion in civil aviation.

The ambition to isolate interfirm price dispersion from intrafirm price dispersion (or price discrimination) may prove impossible to be pursued to its full extent and it may not be desirable to do so either. Airline fare structures are highly complex and so are the differences in those structures between airlines. Dana (1999) finds that in oligopoly markets only a symmetric equilibrium in (dispersed) price distributions exists. He does note however that price specialization can occur if products are “...differentiated in ways other than price.”\(^2\) Since our analysis explicitly focusses on product differentiation as a source of price dispersion, we should not rule out the possibility of price distributions that are asymmetric over firms. Our measure of price dispersion should somehow be able to capture some of that asymmetry, which can only be done if the price distribution is accounted for.

The closest thing to measuring interfirm differences in price distributions without measuring intrafirm price dispersion is focusing at the lowest available fare per airline at a certain point in time. This measure takes into account the (remaining) size of fare classes as well as the dynamics of airlines’ pricing systems. It also accounts for stochastic peak load pricing, but it is not influenced by the availability of higher fare classes. We therefore define interfirm price dispersion in market \( j \) at time \( t \) as the coefficient of variation (\( CV_{jt} \), standard deviation divided by average) of the lowest available fare for each airline in market \( j \) at time \( t \).

Following the discussion in the literature, as well as our theoretical framework in the previous sections, we define three slightly different specifications to be tested empirically. Our first specification follows the main stream in the literature (e.g. Borenstein and Rose, 1994; Gerardi and Shapiro, 2009) and assumes a linear relationship between price dispersion and market concentration, measured by the HHI:

\[
CV_{jt} = \beta_0 + \beta_1 HHI_{jt} + \gamma X_{jt} + \chi w_t + \mu_j + \varepsilon_{jt}
\]  

(12)

Where \( CV_{jt} \) is the coefficient of variation of the fares in market \( j \) at date \( t \), \( HHI_{jt} \) represents the Herfindahl Hirschmann index, \( X_{jt} \) reflects a vector of other characteristics for market \( j \) at time \( t \) (e.g. frequency) and \( w_t \) is a vector of characteristics for time \( t \) that are independent of the market (such as days of the week and the time between booking and flight). We do not have any prior expectations with respect to the sign or impact of vectors \( X_{jt} \) and \( w_t \), but use them to correct for their influence. Following Gerardi and Shapiro (2009), we apply a fixed effects approach, controlling for market fixed effects with \( \mu_j \). Finally, \( \varepsilon_{jt} \) is a disturbance term.

Our second specification follows the suggestion by Dai et al. (2010) that the impact of competition on price dispersion may be non-monotonic. We add \( HHI_{jt} \) squared to equation (12) to account for this possibility.

\[
CV_{jt} = \beta_0 + \beta_1 HHI_{jt} + \beta_2 HHI_{jt}^2 + \gamma X_{jt} + \chi w_t + \mu_j + \varepsilon_{jt}
\]  

(13)

Finally, we develop a specification that is consistent with our framework from the previous sections, using the decomposition of the HHI into a number component and an inequality component:

\[
CV_{jt} = \beta_0 + \beta_3 \left( \frac{1}{N_{jt}} \right) + \beta_4 \frac{V_{jt}^2}{N_{jt}} + \gamma X_{jt} + \chi w_t + \mu_j + \varepsilon_{jt}
\]  

(14)

Where \( N_{jt} \) is the number of firms serving market \( j \) at time \( t \) and \( \frac{V_{jt}^2}{N_{jt}} \) is the market share inequality for market \( j \) at time \( t \), which is defined as \( HHI_{jt} - 1/N_{jt} \). Note that if \( \beta_3 \) is not significantly different from \( \beta_4 \), (14) is equivalent to (12). Moreover, if products are perfectly homogeneous, the results obtained by

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3 Gerardi and Shapiro use carrier-route fixed effects, but given our scope that would not make sense in our approach.
Dana (1999) would imply that $\beta_3 = \beta_4 = 0$. If product differentiation is asymmetric, we would expect $\beta_4 > 0$; $\beta_3 = \beta_4$, based on our theoretical framework.

The relationship between price dispersion and the number of firms does not follow unambiguously from our model. One can argue that the average distance in product space, and hence the average price, will decrease in the number of firms. We have no prior as to the impact of either price differences or market share inequality though. All else equal (which is by no means guaranteed), we would expect interfirm price dispersion to increase with the number of firms ($\beta_3 \leq 0$) due to the denominator effect. Combining the concept of asymmetric product differentiation with Dana’s (1999) result on intrafirm price dispersion also implies $\beta_3 \leq 0$. Dana’s model predicts intrafirm price dispersion to increase in the number of firms. This implies that either the number of fare buckets increases and hence their average size decreases, or the distance between those fare buckets increases (or both). In the first case, the chance of observing different fares at any point in time increases, in the second case, the expected difference between observed fares at any point in time increases.

5. Data and results

Following our discussion in section 2, we measure interfirm price dispersion as the coefficient of variation of the lowest available fare of each airline in a market at a certain date. We collected fares on a daily basis for 12 randomly selected markets originating in Amsterdam, Rotterdam, Eindhoven or Frankfurt on each market varying from a return flight that departures the next day to a flight that departures 60 days from the day of collecting. All fares are based on 7-night return tickets, so that a Saturday night was included in all flights. Time preferences were ignored and besides bringing one piece of luggage no flexibility options were selected. HHI indices per day and market are calculated based on seats offered by each airline on each day and market. Other variables collected for each day and market are the total frequency, the number of firms offering services, the number of days before departure and the day of the week of departure.

On some routes, one or both sides of the route had airports from a multi-airport region. For those routes, we analyzed partial correlations between daily fares, controlling for the number of days before departure, to identify close substitutes. Based on this analysis, we concluded that all routes from Amsterdam to any of the London airports should be treated as a single market. Likewise, we treat the routes Amsterdam-Hamburg and Rotterdam-Hamburg as a single market. On some markets and days, only one airline offered services (68 obs). Those temporary monopoly markets were removed from the dataset, as they do not fit into our framework. By construction, monopoly markets have a unity HHI and zero price dispersion and market share inequality, which would seriously distort the empirical analysis.

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4 Data was collected on Monday 3 May 2010 and Friday 21 May 2010, from the websites Expedia.nl, Ryanair.com, Singaporeair.com and Transavia.com. Ticket prices were always rounded up to whole Euros.

5 Number of seats were calculated using airline timetables and number of seats by airplane type and airline from http://www.seatmaestro.com
In addition, nine observations were deleted due to missing data. Table 1 below provides descriptive statistics for the data used in our analysis.

<table>
<thead>
<tr>
<th>Variable</th>
<th>mean</th>
<th>Standard deviation</th>
<th>minimum</th>
<th>maximum</th>
</tr>
</thead>
<tbody>
<tr>
<td>CV of lowest available fare</td>
<td>0.27</td>
<td>0.23</td>
<td>0</td>
<td>1.18</td>
</tr>
<tr>
<td>HHI</td>
<td>0.53</td>
<td>0.13</td>
<td>0.27</td>
<td>0.79</td>
</tr>
<tr>
<td>Inverse number of firms</td>
<td>0.44</td>
<td>0.09</td>
<td>0.25</td>
<td>0.5</td>
</tr>
<tr>
<td>Market share inequality</td>
<td>0.09</td>
<td>0.09</td>
<td>0.00</td>
<td>0.29</td>
</tr>
<tr>
<td>Flight frequency</td>
<td>9.82</td>
<td>10.80</td>
<td>2</td>
<td>46</td>
</tr>
</tbody>
</table>

Number of observations by number of firms

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>937</td>
</tr>
<tr>
<td>3</td>
<td>306</td>
</tr>
<tr>
<td>4</td>
<td>120</td>
</tr>
<tr>
<td>Total</td>
<td>1363</td>
</tr>
</tbody>
</table>

On average, our variable reflecting price dispersion is 0.27, implying that in our average observation, the standard deviation of the fare is slightly over one quarter of the average fare for that observation. For some cases, no fare dispersion is found, whereas in others the standard deviation of the fares exceeds the fare level. The majority of our observations comes from duopoly markets, leading to a fairly high average inverse number of firms. All observation have some market share inequality, although the minimum is close to zero.

We estimated equations 12 through 14, controlling for market fixed effects. Table 2 presents the result of our empirical analysis.
Table 2 Empirical results, dependent variable CV of lowest fare (standard errors in parentheses)

<table>
<thead>
<tr>
<th>variable</th>
<th>parameter</th>
<th>Model 1 (eq 12)</th>
<th>Model 2 (eq 13)</th>
<th>Model 3 (eq 14)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Constant</td>
<td>$\beta_0$</td>
<td>0.259**</td>
<td>0.843**</td>
<td>0.380***</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(0.040)</td>
<td>(0.213)</td>
<td>(0.044)</td>
</tr>
<tr>
<td>HHI</td>
<td>$\beta_1$</td>
<td>0.155*</td>
<td>-1.880**</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(0.075)</td>
<td>(0.733)</td>
<td></td>
</tr>
<tr>
<td>HHI$^2$</td>
<td>$\beta_2$</td>
<td>-</td>
<td>1.656</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(0.594)</td>
<td></td>
</tr>
<tr>
<td>Inverse of number of firms</td>
<td>$\beta_3$</td>
<td>-</td>
<td>-</td>
<td>-0.276**</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>(0.100)</td>
</tr>
<tr>
<td>Market share inequality</td>
<td>$\beta_4$</td>
<td>-</td>
<td>-</td>
<td>0.892**</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>(0.132)</td>
</tr>
<tr>
<td>Days to departure</td>
<td>$\chi_1$</td>
<td>-0.001**</td>
<td>-0.001**</td>
<td>-0.001**</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(0.000)</td>
<td>(0.000)</td>
<td>(0.000)</td>
</tr>
<tr>
<td>Departure on Monday</td>
<td>$\chi_2$</td>
<td>-0.044**</td>
<td>-0.047**</td>
<td>-0.035**</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(0.012)</td>
<td>(0.012)</td>
<td>(0.011)</td>
</tr>
<tr>
<td>Departure on Friday</td>
<td>$\chi_3$</td>
<td>-0.050**</td>
<td>-0.047**</td>
<td>-0.043**</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(0.012)</td>
<td>(0.012)</td>
<td>(0.012)</td>
</tr>
<tr>
<td>Departure on Saturday</td>
<td>$\chi_4$</td>
<td>-0.057**</td>
<td>-0.046**</td>
<td>-0.077**</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(0.014)</td>
<td>(0.015)</td>
<td>(0.014)</td>
</tr>
<tr>
<td>Departure on Sunday</td>
<td>$\chi_5$</td>
<td>-0.090**</td>
<td>-0.078**</td>
<td>-0.094***</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(0.012)</td>
<td>(0.013)</td>
<td>(0.012)</td>
</tr>
</tbody>
</table>

F         | 16.7      | 15.5           | 21.2           |
R$^2$ within | 0.07      | 0.07           | 0.10           |
R$^2$ between | 0.25      | 0.10           | 0.36           |
R$^2$ overall | 0.10      | 0.08           | 0.22           |

* significant at the 5% level ** significant at the 1% level

The empirical results are by-and-large consistent with our theoretical framework. The results for model 3 establish that $\beta_4 > 0$; $\beta_3 \neq \beta_4$, which is what our theoretical model predicts. This finding is confirmed in model 2, where the parameter values of $\beta_3$ and $\beta_4$ imply that price dispersion is increasing in concentration at HHI levels of 0.57 and higher. We note that from 0.5 onwards market share equality is the main—if not only—source of concentration, implying that model 2, like model 3, reflects that market share inequality is positively related to interfirm price dispersion. Moreover, we find that $\beta_3 < 0$, which is consistent with the model by Dana (1999).

The impact of the number of days to departure is small and negative and robust to the model specification. The parameter for frequency was not statistically different from zero and was hence eliminated from the model. Monday and Friday, and even more so, Saturday and Sunday negatively impact the level of price dispersion. These are typically days with relatively high numbers of leisure travelers, who are likely to be more price sensitive than passengers on a business trip. In terms of our theoretical framework, their willingness to pay for the differences in product characteristics (transport costs in the spatial competition model) is lower. This implies that the scope for price dispersion is lower on days when leisure is the main trip purpose and firms have to match each other’s prices.
6. Conclusion

This paper argues that interfirm price dispersion may be caused by unobserved product differentiation. Based on the pricing stage of the Hotelling model of spatial competition, we show that asymmetric spatial competition leads to interfirm price dispersion as well as market share inequalities. We test our theoretical findings using airline ticket fare data. We approximate interfirm differences in prices by the coefficient of variation of the lowest available fare per airline at a certain day in a certain market and control for market fixed effects in our analysis. We decompose the Hirschmann Herfindahl index to separate the effect of the number of firms in a market from market share inequality.

The results of our empirical analysis are consistent with the conclusions of our theoretical framework and suggest that share inequality is positively related to interfirm price dispersion. Moreover, the empirical results suggest that using the HHI to measure the impact of the level of competition on price dispersion in a market is likely to provide biased results. Our empirical results are also consistent with the findings of Dana (1999) on interfirm price dispersion and it may be fruitful to extend our theoretical framework to intrafirm price dispersion along these lines.

References


