Pricing and Demand Uncertainty in the Newsvendor Model: Evidence from the Newsstand*

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Abstract
Demand uncertainty impacts both the price and inventory decisions of firms in the classic newsvendor model, however greater uncertainty may be associated with either higher or lower prices depending on whether demand uncertainty is multiplicative or additive. Using price and sales volatility for US and Canadian magazines, I find empirical evidence, consistent with multiplicative demand uncertainty, that publishers set higher newsstand prices for magazines with greater sales volatility. The empirical evidence is strongest when I restrict the sample to weekly magazines, presumably because their inventory is more difficult to replenish. The evidence for multiplicative demand uncertainty is strong even when I also control for magazine heterogeneity using the subscription price and using magazine fixed effects.

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1 Introduction

The newsvendor model characterizes the optimal inventory decision of a single-period firm, that is, a firm that chooses its inventory once and cannot replenish its inventory. The classic example used to motivate the model is a newsstand because a newsstand makes a single inventory decision for each of its products. The newsvendor model also has important implications for pricing, though the impact of uncertainty on prices depends on the shape of the demand function. Intuitively, increased uncertainty can increase the expected costs per sale (greater overage costs), which suggests a higher optimal price, and increased uncertainty can also make expected demand more price sensitive (more elastic), which suggests a lower optimal price. In fact, which effect is larger depends on the shape of the demand curve. On the one hand, when the elasticity of demand is invariant to demand shocks, as happens when demand uncertainty is multiplicative, the increased uncertainty only increases expected costs per sale, so the optimal price is higher. On the other hand, when the variance or volatility of demand is unaffected by changes in price, as happens when demand uncertainty is additive, then greater uncertainty has no effect on the marginal expected cost (the marginal cost of additional output associated with a price decrease), but does increase the elasticity of expected sales with respect to price, so the optimal price is lower.

This is the first paper to empirically test whether firms set higher or lower prices when demand is more volatile. I consider a both a cross-section and a panel sample of prices and historical sales volatility for US and Canadian magazines. I show that all else equal, newsstand prices are higher for magazines with greater sales volatility. More specifically, I show that newsstand price is higher when the coefficient of variation is higher, that is, when the standard deviation of sales is greater holding the mean fixed (the coefficient of variation is the ratio of the standard deviation to the mean). The sales volatility is calculated using historical aggregate sales, which is a reasonable estimate of an individual retailer’s volatility under the assumption that retailers face highly correlated demand shocks.\footnote{The source of these common demand shocks could be current events that change preferences, such as television appearances of movie stars, or uncertainty about preferences, such as the appeal, or lack of appeal, of a photo or headline placed on the magazine’s cover.}

The price of magazines varies with many magazine characteristics besides demand volatility, including the costs of printing and delivery, the elasticity of demand, and the advertising revenues. Many of these are observable to the publisher and hence influence
the price, but are unobservable to me. So if any of these unobservable characteristics are correlated with the magazine’s demand uncertainty, then the estimation results will be biased.

I control for many unobservable magazine characteristics (including many time-varying magazine characteristics) by using the price of magazine subscriptions. The subscription version of a magazine has the same printing costs, generates the same advertising revenues, faces competition from the same rivals, and shares many of the same demand characteristics as the newsstand version. Moreover, the subscription sales are essentially known at the time of printing, so the difference between the newsstand and subscription price can plausibly be attributed to the volatility of newsstand sales. Hence the main estimation method in both the cross section and panel data analysis is a differences-in-differences estimator. In my panel regressions, I also control for other time-invariant magazine characteristics using magazine fixed effects.

All of my estimates are consistent with multiplicative demand uncertainty. And the relationship between price and volatility is largest withing magazines published weekly, presumable because inventory replenishment is most difficult for these magazines.

2 Related Literature

The optimal price and inventory decisions in the newsvendor model are studied by Mills (1959) for additively separable demand (or additive uncertainty) and by Karlin & Carr (1962) for multiplicatively separable demand (or multiplicative uncertainty). Mills finds that the price under uncertainty is never higher than the price under certainty, while Karlin & Carr (1962) find the opposite result. Petruzzi & Dada (1999) is the first paper to examine a unified framework that encompasses both additive and multiplicative uncertainty. Salinger & Ampudia (2011) also examine a unified framework and give a more intuitive characterization of the way that uncertainty alters pricing decisions. More specifically, Salinger & Ampudia (2011) show that under multiplicative uncertainty, greater uncertainty induces the firm to price as if its marginal cost is higher (implying a higher price) while under additive uncertainty, greater uncertainty induces the firm to price as if its

\(^2\)Another important documented difference between the newsstand and subscription demand is behavioral differences between consumers making present consumption decisions and consumers making future consumption decisions (see the discussion of Oster & Scott Morton (2005) below).
demand is more elastic (implying a lower price). Empirical research on the newsvendor model has primarily focused on inventory decisions. For example, Levitt (2006) examines the inventory decisions of a donut and bagel vendor and finds the decisions (made daily across many self-service locations) are very close to optimal. Levitt (2006) controls for the substitution between bagels and donuts once one product becomes stocked out, so the underage cost is the forgone price-cost margin less the expected profit margin on the substitute good and the overage cost is the firm’s wholesale supply price.

Olivares, Terwiesch & Cassorla (2008) observe that a significant challenge for research on inventory decisions is that the opportunity costs associated with a stockout, or underage costs, are unobservable. In practice firms often hold more inventory than the simple newsvendor model predicts, a stylized fact that is consistent with the view that the underage cost should also include lost future sales or lost reputation and not just lost current profits. Instead of asking whether inventory decisions are optimal, Olivares et al. (2008) estimate a structural newsvendor model that uses observed inventory decisions to estimate the implied underage and overage costs. They analyze the scheduling of scarce operating rooms in a hospital. Their hospital must consider the tradeoff between the costs of idle operating rooms and the cost of making hospital employees and their patients wait for a free operating room. They find that the hospital’s scheduling decisions imply a large value of idle capacity, or equivalently a very large cost of delaying surgery.

Matsa (2011) shows that greater competition is associated with higher inventory and service levels. Matsa (2011) uses Bureau of Labor and Statistics price index data to measure stockouts at grocery stores and shows that grocery stores’ stockouts decline when competition increases. He documents correlation between stockouts and cross-sectional differences in the number of rival stores and as well as decreases in stockouts over time following the entry of a local Wal-Mart retail store. Increased competition presumably leads to higher stockout costs because competition makes it more likely consumers will switch stores after a bad experience with stockouts, though competition should also reduce margins, which reduces the cost of stockouts.

Conlon & Mortimer (2013) introduce an empirical methodology for measuring consumer preferences and substitution patterns in the presence of stockouts in their discrete choice

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demand estimation of sales in vending machines. Anderson, Fitzsimons & Simester (2006) explicitly measure the cost of stockouts and confirm that stockouts not only significantly impact future sales, but they also reduce the sales of other products during the same shopping episode. That is, the simple newsvendor model may understate current underage costs as well as ignore future profit losses.\footnote{The fact that the costs of stockouts are complex and difficult to measure has also been noted in several operations textbooks (see Karlin & Carr (2000) and Raman (1999)) and is thought to be an important reason the newsvendor model is not more widely used in practice.}

Finally, other research has focused on the magazine industry. Oster & Scott Morton (2005) also compare newsstand and subscription prices. They show that magazine prices are consistent with behavioral biases in consumer decision making. Specifically, they argue that publishers set the prices of their magazines as if consumers are biased towards immediate gratification when making decisions at the newsstand (immediate consumption), but care more about the long-run consumption benefits when making decisions about subscriptions (which are a type of future consumption). Consistent with their theory, they find that magazines that offer an investment in knowledge or skills (a high future benefit) have a higher ratio of subscription to newsstand prices than leisure-oriented magazines. Ferrari & Verboven (2012) use the magazine industry to empirically measure the profitability of market-specific wholesale prices and other vertical restraints used by suppliers. Kaiser & Wright (2006) estimate a two-sided market model and find evidence that readers may place positive value on advertising in magazines, and more generally that publishers subsidize magazine sales using lower cover prices in order to increase profits from advertisers through higher advertisement prices, a result to the fact that advertisers’ demands are relatively less elastic than readers’ demands.

\section{Data}

The data comes from the circulation audit reports of US and Canadian magazines produced by the Audit Bureau of Circulations (or ABC), which was renamed the Alliance for Audited

\footnote{Inventory may also influence sales directly. Cachon, Gallino & Olivares (2013) show that excess inventory within an automobile variety directly leads to increased sales.}
\footnote{Aguirregabiria (1999) and Aguirregabiria (2005) also consider dynamic models of price and inventory decisions.}
Media (or AAM) in 2012. The AAM is a non-profit organization whose primary function is to provide potential advertisers authenticated circulation figures on newspapers and magazines in the US and Canada.

The audit reports from the AAM contain detailed circulation counts for each issue of each magazine reported separately for single-copy (or newsstand) sales and for subscription sales. The circulation for 1991 to 2000 comes from hard copies of AAM’s audit reports for 2000, and the circulation for 2004 to 2013 comes from AAM’s online database. Reported single-copy sales circulation is an aggregate of single-copy sales across all retailers.

The AAM’s audit reports also provide the list price for single-copy and subscription sales. While the single-copy price is rarely discounted by retailers, the subscription price is commonly discounted. The audit report lists the available discounted subscription prices, but does not report the breakdown of sales at each price, so in my empirical analysis I use the list price for both single-copy and subscription sales.

Magazine prices also are come from AAM’s audit reports for 2000 and from AAM’s online database for 2004 to 2013, however the 2000 reports do not contain historical price data, only historical circulation data. The sample statistics are reported in Tables 1 and 2. Prices and issues per year in Table 1 are for 2000 (the December price), while the mean and standard deviation (SD) of single-copy sales in Table 1 is calculated from circulation figures for 1991 to 2000 that are in the 2000 reports. Table 1 reports statistics for 559 magazines.

In Table 2, I report summary statistics for the end-of-year price and for the mean and standard deviation of circulation calculated using the current year’s circulation data. Table 2 reports statistics for 448 magazines. The panel data set is unbalanced and includes magazines that enter and exit during 2004 to 2013. The average length of time that one of the 448 magazines is in the panel is close to 9 years.

4 Optimal Pricing in the Newsvendor Model

While magazines clearly compete with one another, I assume that the magazine market is monopolistically competitive so that each magazine can be treated as a local monopolist with respect to price and inventory decisions. I also ignore the fact that some publishers produce many magazines, so that the price and inventory of one magazine is not a function of the characteristics of the publisher’s other magazines. And while publishers and retailers
are separately-owned companies (i.e., newsstands typically make their own inventory decisions), I assume that the vertical contracts which exist between publishers and newsstands perfectly coordinate the supply chain so that I can assume the price and inventory decision maximizes the supply chain's profit function.

Following Salinger & Ampudia (2011) and Petruzzi & Dada (1999), I consider a basic newsvendor model with demand $Q(\epsilon, p)$, where $\epsilon$ is a random variable characterizing the demand state and $p$ is the price, and with manufacturing cost $c$ per unit of inventory. The firm chooses a price and stocking factor, $z$, which is equivalent to choosing price and inventory since there is a one-to-one mapping from the stocking factor to the inventory, $Q(z, p)$, associated with any price, $p$. Letting $Q^e(z, p) = \mathbb{E}_\epsilon \left[ \min\{Q(\epsilon, p), Q(z, p)\} \right]$ denote the expected sales, the expected profit function can be written as $\Pi(p, z) = pQ^e(z, p) - cQ(z, p)$.

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\[^6\text{Magazines also generate revenue from advertisements, so } c \text{ can loosely be construed to be the cost net of advertising revenue, but advertising revenue typical varies with sales rather than printed copies, so advertising should effect the cost of subscription and single-copy sales differently, which makes this is an imperfect assumption (see Appendix B for a more general framework with advertising revenue).}\]
Salinger & Ampudia (2011) show that $z = F^{-1}((p - c)/p)$ is the supply chain’s optimal stocking factor, and that the optimal price is

$$ p = \frac{\eta^e(z)}{1 + \eta^e(z)} c^e(z); \tag{1} $$

where $F(\cdot)$ is the cumulative distribution function of $\epsilon$; where

$$ \eta^e(z) = \frac{\partial Q^e(z,p)}{\partial p} \frac{p}{Q^e(z,p)} \tag{2} $$

is the elasticity of expected sales with respect to price holding the stocking factor fixed; and where

$$ c^e(z) = \frac{\partial Q(z,p)/\partial p}{\partial Q^e(z,p)/\partial p} c \tag{3} $$

is the expected marginal cost, i.e., the expected additional production cost associated with increasing expected sales by one unit through a price decrease while holding the stocking factor fixed.

Taking the log of both sides, equation (1) becomes

$$ \ln p = \ln \left( \frac{\eta^e(z)}{1 + \eta^e(z)} \right) + \ln \left( \frac{\partial Q(z,p)/\partial p}{\partial Q^e(z,p)/\partial p} \right) + \ln c. \tag{4} $$

Under additive uncertainty the demand function is $Q(\epsilon, p) = q(p) + \epsilon$, which implies that $\partial Q(z,p)/\partial p = \partial Q^e(z,p)/\partial p$ and hence the second term vanishes. Moreover, $\partial Q^e(z,p)/\partial p$ does not depend on the distribution of $\epsilon$, so a mean preserving spread of $\epsilon$ lowers $Q^e(z,p)$, and makes expected sales more elastic (i.e., make $\eta^e(z)$ more negative), which implies a the optimal price decreases when uncertainty increases.

Under multiplicative uncertainty the demand function is $Q(\epsilon, p) = q(p)\epsilon$, so $\eta^e(z) = q'(p)p/q(p) = \eta$, which is independent of $\epsilon$. Hence a mean preserving spread of $\epsilon$ has no effect on the first term. However clearly $\partial Q(z,p)/\partial p$ is unaffected by a mean preserving spread of $\epsilon$, and $\partial Q^e(z,p)/\partial p = q'(p)E_\epsilon [\min \{ \epsilon, z \}]$ falls, so the optimal price increases when uncertainty increases.

In addition to having different pricing implications, multiplicative and additive uncertainty also differ distinctly in the underlying assumptions on consumer preferences. Intuitively, if consumers purchase just one unit of the good and each has a random valuation drawn from the same distribution function, then the uncertainty can impact either
the number of consumers or the distribution of their valuations, or both. Multiplicative uncertainty is consistent with uncertainty about the number of consumers when consumers have the same distribution of valuations. So when demand is high, the share of consumers with valuations above the price is unchanged. On the other hand, additive uncertainty describes the case in uncertainty doesn’t effect the number of consumers but instead shifts every consumers’ valuation distribution up or down. More consumers may buy the good, but because more have valuations in excess of the price. The difference in terms of pricing is significant. If firms could adjust price to market demand, then in the former case the profit maximizing price is not effected by changes in demand, while in the later case the profit maximizing price clearly increases as demand increases. Of course in practice, and in the theoretical model, magazine prices are set before uncertainty is resolved. So if the uncertainty is only about the number of consumers, and not their preferences, then multiplicative uncertainty seems more plausible. On the other hand, if the uncertainty is about some common shock to consumers’ preferences, such as a major news or entertainment event, then additive uncertainty seems more plausible.

5 Estimation

Equation (4) implies that a regression of the log of newsstand price on sales volatility is a test which of the two effects is stronger, and whether additive uncertainty or multiplicative uncertainty is a better approximation for demand uncertainty in the magazine industry. However such a regression would ideally hold everything else equal, including costs, advertising, the demand elasticity, and expected sales, yet it is likely that some or all of these change across magazines and potentially across time. If these omitted variables are correlated with the uncertainty, then the coefficient on volatility will be biased.

A natural way to control for unobserved variation across magazines is by controlling for the subscription price. Subscriptions have the same printing costs, advertising income, and to a large extent, the same demand characteristics (including the elasticity of demand) as single-copy sales, but are produced to order and not produced to stock. Indeed the subscription price satisfies

\[ \ln p_{sub} = \ln \left( \frac{\eta}{1 + \eta} \right) + \ln c, \]  

(5)

\footnote{More precisely, additive uncertainty implies that the number of consumers whose valuation exceeds any price increases by the same amount regardless of what that price is.}
where $\eta = (\partial Q_{sub}(p)/\partial p)(p_{sub}/Q_{sub}(p))$ and $Q_{sub}(p)$ is the known subscription demand. Taking the difference between the two prices yields

$$\ln p_{sc} - \ln p_{sub} = \ln \left( \frac{\eta e(z)}{1 + \eta e(z)} \right) - \ln \left( \frac{\eta}{1 + \eta} \right) + \ln \left( \frac{\partial Q(z, p)/\partial p}{\partial Q^e(z, p)/\partial p} \right),$$

(6)

where the single-copy or newsstand price is denoted by $p_{sc}$.

Equation (6) forms the basis of my main regressions. I regress the difference between the log of the newsstand price and the log of the subscription price on the difference between the sales volatility of newsstand and subscription sales, where I assume subscription sales have zero volatility. This difference specification eliminates omitted variable bias that arises when newsstand sales volatility is correlated with unobserved magazine characteristics that are unchanged between the single-copy sales and subscription markets.

Besides controlling for magazine characteristics, it is also important to control for the expected circulation of the magazine. In a cross section data set, the standard deviation (SD) of sales is highly correlated with the mean of sales. It is natural to expect that magazines with higher expected sales will also have greater standard deviations. In order to control for variation in the expected sales across magazines, I use the log of the coefficient of variation (CV) as my preferred measure of sales volatility. The coefficient of variation is the ratio of the standard deviation to the mean, so an increase in the coefficient of variation essentially holds the mean fixed even when comparing across magazines with different means and standard deviations.

In fact, under multiplicative uncertainty, and other reasonable assumptions, the difference in prices is an increasing function of the coefficient of variation. Appendix A describes that relationship more formally.

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8Under additive uncertainty the standard deviation is independent of the price, but the standard deviation could nevertheless vary proportionally with the expected sales.
Dependent Variable: $\ln(p_{sc}) - \ln(p_{sub})$

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*p < 0.05, ** p < 0.01, *** p < 0.001

Table 3: Year 2000 Cross-Section Regressions
5.1 Year 2000 Cross-Section Regressions

I begin by analyzing a cross section of 559 magazines in the year 2000. A significant advantage of this data set is that the year 2000 is well before changes in online advertising induced significant structural changes in the magazine industry. Another important advantage is that I can generate a more accurate measure of the mean and standard deviation of single copy sales using 10 years of historical circulation data. A disadvantage of using this data set is that I can only control for unobservable magazine characteristics using the subscription price, and I cannot use magazine fixed effects.

Table 3 shows the estimation results. Column 1 reports a regression of the difference between the log of the newsstand price and the log of the subscription price on the log of the standard deviation of historical sales. This is a difference-in-difference estimation since I interpret the newsstand volatility as the difference in the newsstand volatility and the subscription volatility (the later is zero since the subscription demand is known at the time of printing). The coefficient on the log of the standard deviation of historical sales is not statistically different from zero. Column 2 adds a control for the mean of sales since a large part of the variation in the standard deviation of sales across magazines is associated with differences in the mean.

A more direct way to control for expected sales is to use the coefficient of variation instead of the standard deviation as my measure of volatility. Column 3 reports a regression of the difference between the log of the newsstand price and the log of the subscription price on the coefficient of variation of newsstand sales. The use of the coefficient of variation is theoretically justified, and more importantly it is empirically justified given the coefficients on the log of the standard deviation and the log of the mean in Column 2. Specifically, \( \ln(CV) = \ln(SD/\text{Mean}) = \ln(SD) - \ln(\text{Mean}) \), and I cannot reject that the hypothesis that the coefficient on the mean is equal to \(-1\) times the coefficient on the standard deviation.

Another estimation concern is endogeneity. It is unlikely that the underlying demand uncertainty is influenced by price, but the measure of demand uncertainty that I use is historical sales volatility, which probably is influenced by price because reported sales are a censored measure of demand. Sales are equal to demand if inventory is sufficient to meet demand, but equal to the available inventory otherwise. As a consequence, higher cost magazines (all else equal) will have a higher price and a lower optimal stocking factor and hence lower sales volatility even if the underlying demand uncertainty is the same. So a high price could lower the expected sales by more than it lowers the standard deviation.
of sales. However this implies that there is a negative relationship between price and uncertainty, which would introduce a downward bias in the coefficient on sales volatility in the regressions. So I think the conclusion that demand uncertainty is multiplicative is even stronger.

Also, variation in advertising revenues or demand would effect both the subscription and the single-copy price, so differences in advertising revenue across magazines are probably controlled for with the difference-in-difference estimation strategy.

I next consider the results separately for weekly magazines. Clearly replenishment of inventory is more feasible for monthly and quarterly magazines than for weekly magazines. If newsstands can replenish inventory, either through new printing or through inventory exchanges with other newsstands, then the cost of demand uncertainty is lower. That is, a weekly magazine with the same standard deviation of expected value of sales as a quarterly magazine will typically require more ex ante inventory and will therefore result in greater average excess. Under multiplicative uncertainty, this implies the price premium for weekly magazines, relative to the subscription price, will be higher.\footnote{As a robustness check I also calculated the mean, standard deviation, and coefficient of variation after omitting the circulation of the largest issue in each calendar year. The idea was that some variation might be due to special issues (Time magazine’s person of the year or Sports Illustrated magazine’s swimsuit issue) but this had no noticeable impact on the estimates.}

Columns 4 though 6 in Table 3 report the regressions estimated on just the 50 weekly magazines in my data set. As expected, the coefficient on weekly magazines is much larger and more significant. Indeed, relationship between uncertainty and price is statistically insignificant for the 509 other magazines, but is so strong for the 50 weekly magazines that the relationship is significant in the overall sample. Of course, it is possible that demand uncertainty is multiplicative in weekly magazines but not in the others. But perhaps a more plausible explanation is that inventory replenishment is feasible for many monthly magazines, so annual sales volatility for monthly and quarterly is not a good measure of the expected costs of excess inventory.

\footnote{As a robustness check I also calculated the mean, standard deviation, and coefficient of variation after omitting the circulation of the largest issue in each calendar year. The idea was that some variation might be due to special issues (Time magazine’s person of the year or Sports Illustrated magazine’s swimsuit issue) but this had no noticeable impact on the estimates.}

Of course the more general problem is that some of the variation in demand is predictable while some of it is unexpected. Failure to control for predictable variation in single-copy demand could bias the coefficients in either direction, but if the variation in the predictable portion of demand is independent across magazines, then it is analogous to measurement error and it would bias the coefficient on volatility towards zero.
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* p < 0.05, ** p < 0.01, *** p < 0.001

Table 4: Year 2004 to 2013 Panel Regressions
5.2 The 2004 to 2013 Panel Regressions

I perform a similar analysis using my 2004 to 2013 panel data set. The advantages of using the panel data are first that I can control for unobserved variation across magazines using fixed effects, and second that I have many more observations. However a significant disadvantage is that I do not have relevant historical sales data to measure the mean and standard deviation of single copy sales, and using only the current year’s circulation to estimate the mean and standard deviation of sales introduces additional measurement error and attenuation bias. In addition, I use the December magazine prices for each year, but because of rigidity in prices, it isn’t clear that the December price fully reflects changes in sales volatility observed earlier in the year, which also increases attenuation bias.

The results in Table 4 without magazine or year fixed effects are almost exactly the same as the results obtained above for the year 2000. And again, the estimates are much larger for weekly magazines (Columns 1 and 4). This is notable since the impact of online distribution has clearly dramatically changed the industry during this time period.

When just magazine fixed effects are included, the coefficient on the volatility is still positive and statistically significant (Columns 2 and 5), but the magnitude is smaller. And the coefficient is still much higher when the sample is restricted to weekly magazines.

The smaller coefficients may reflect the fact that using the subscription price is not adequate for controlling for the unobserved variation across magazines and that some of this unobserved variation is correlated with volatility. However, it may simply reflect the increase in attenuation bias caused by adding fixed effects. Recall that volatility is measured with error, particularly in the panel regression in which only one year of circulation is used to compute the standard deviation, and that this measurement error is very random and not correlated with magazine characteristics. Because magazine fixed effects are likely to absorb a great deal of the cross sectional variation in volatility, adding fixed effects increases the attenuation bias introduced by measurement error (see Griliches & Hausman (1986)).

Again, prices changed very infrequently, and when they do, they may be responding to historical changes in volatility as opposed to concurrent changes. Consistent with this, note that Table 4 shows that about 90 percent of the variation in prices is explained by magazine fixed effects. That is, prices differences across magazines are significantly larger than differences in magazines across time. Since the magazine fixed effects estimation is based on changes in volatility over time (noisy) and not on changes in volatility across magazines (much less noisy), attenuation bias is largely increased, particularly if price
changes are not contemporaneous with volatility changes.

Table 4 shows that when year fixed effects are included (Columns 3 and 6), then the coefficient on the coefficient of variation is still positive but is no longer statistically significant, though it is still much larger when the sample is restricted to weekly magazines.

These results are disappointing, but once again, it is possible that the attenuation bias is even larger in these regressions. When both magazine and year fixed effects are included, the coefficient on volatility is being identified by changes in volatility over time that are different across magazines, and by the corresponding changes in prices. However to the extent that publishers adjust their magazine prices simultaneously (perhaps because of price rigidities, or perhaps for other behavioral and strategy reasons), the attenuation bias is likely to be even larger. Publishers might also use the volatility of related magazines to forecast magazine volatility, which would also increase attenuation bias in these regressions since the volatility after controlling for time and year fixed effects.

While not reported here, the coefficients in the panel regressions are larger when the sample is restricted to 2004 to 2008, before the great recession. It may be the the recession had a significant structural impact on magazine pricing. And whether it directly impacted pricing or not, it is a major reason for declining advertising revenues and sales revenues which lead to the exit of many magazines and would have indirectly affected pricing. Of course the other major structural change that occurred in the past decade was a shift from print advertising to online advertising, so magazine profitability would have declined significantly even absent the recession. Note however that it is not immediately obvious why these structural changes should have affected the estimates, so I report the results for the greatest number of observations.

Finally, as a robustness check, I estimated the model using 2 to 4 years of historical circulation to calculate the standard deviation of single copy sales. In principle, this should reduce attenuation bias by reducing measurement error, but these regressions yielded only minor increases in the size of the coefficients which weren’t large enough to be statistically significant given that this also reduces the number of observations.

6 Discussion

Several oversimplifications in the model and the estimation deserve attention. First, the model ignores stockout costs besides the cost of lost sales despite ample evidence that firms set much higher inventory than predicted by a newsvendor model. This omission directly
impacts the optimal stocking factor, but it is unlikely to impact the price analysis since the price analysis holds the stocking factor fixed. Furthermore, a higher stocking factor implies less truncation and makes historical sales volatility a better measure of demand uncertainty.

Second, publishers sell through retailers who might have an incentive to distort inventory and pricing decisions. I assumed the vertical contracts allow the retailers and the publisher to perfectly coordinate the supply chain and maximize joint profits. This may justified because publishers use returns contracts and revenue sharing contracts to align incentives, but no vertical contract can do so perfectly. The main concern is that the newsstand is vertically separated and the subscription market is not, so vertical separation might cause higher prices in the single-copy channel. In particular, the classic double markup problem would imply higher prices for single copy sales. However, this is unlikely to induce bias because newsstands do not set the retail price. With few exceptions, newsstands charge the list price printed on the magazine cover, and this price is clearly set by the publisher.

Third, the model treats the market as if there were a single newsstand, but in fact there are many small newsstands. This is important, because uncertain demand stems from two sources, the aggregate uncertainty that arises because it is difficult to forecast how popular a particular issue of a magazine will be and the idiosyncratic uncertainty the arises because the newsstand faces a finite number of consumers each with idiosyncratic shocks. In general, small newsstands will face greater uncertainty than one large newsstand. In particular, the standard deviation of demand relative to the mean at each newsstand will grow as the demand is divided between more newsstands, except in the very unlikely case that all demand uncertainty is aggregate uncertainty and demand is perfectly correlated at each newsstand. However, I am implicitly assuming that this additional factor increases the markup equally across magazines.

Fourth, I assume that costs are equal across the two distribution channels, that is, that $c = c_{sub} = c_{sc}$. Printing costs are basically the same, so this assumption is equivalent to assuming that the mailing costs of a subscription magazine be equal to the shipping costs to the retail plus the incremental sales and handling costs of the retailer. Note that this assumption cannot be verified using average cost data because it is difficult to know how much of these costs to treat as variable and how much to treat as fixed. More importantly, the estimates are unbiased under the weaker assumption that $c_{sc}/c_{sub}$ is constant across magazines. In fact, the estimates are only biased if the variation in this ratio across
magazines is correlated with the variation in demand uncertainty.

Finally, advertising revenues are also relevant to pricing decisions. For subscription sales, advertising are just equivalent to negative costs, but for newsstand sales it is reasonable to describe advertising revenue as a negative cost for sold inventory but not for unsold inventory. This could introduce a potential bias, particularly in the cross-section econometric estimation, if advertising revenue is correlated with uncertainty. In Appendix B, I study at the multiplicative uncertainty model with advertising revenues and discuss this potential bias in more detail.

7 Conclusion

The paper examines magazine pricing at the newsstand and finds that magazines with more uncertain sales have higher newsstand prices, particularly within magazines that are issued weekly. The estimation uses differences in the newsstand price and the subscription price as the dependent variable in order to control for unobserved variation in magazine characteristics such as printing costs, consumer preferences, and advertising revenues, and uses the coefficient of variation as the measure of uncertain sales in order to control for variation in expected sales. The relationship is strongest for weekly magazines suggesting that inventory replenishment may be common for magazines published monthly or quarterly.

This result is consistent with multiplicative demand uncertainty. Of course, prices are set by firms which may or may not know whether the demand uncertainty they face is multiplicative or additive. The results of this paper suggest that they behave as if the uncertainty is multiplicative. Publishers do not adjust prices often, but they do publish many magazines. So I think it is plausible that they realize how a price change on average effects the volatility of demand. Nevertheless, it is important to emphasize that this paper tests what publishers perceive about their demand uncertainty, not the actual form of that uncertainty.

Perhaps more critically, the estimates are also consistent with publishers following simple markup rules. That is, if publishers ignore the impact of uncertainty on the elasticity of demand, and instead simple markup the expected unit costs by a fixed percentage, then magazines with more volatile demand will have higher expected unit costs (more waste holding printing costs fixed). So again, the evidence is consistent with multiplicative demand uncertainty, but does not establish even that firms perceive demand uncertainty is multiplicative, only that (all else equal) prices are higher when demand is more volatile.
Finally, the cross-section evidence is stronger than the panel data evidence. This could be because of the dramatic changes to the print magazine industry stemming from the growth in alternative online advertising platforms and the great recession, however the 2004 to 2013 results are only slightly smaller than the 2000 results when time fixed effects are not included. As previously mentioned, the results with fixed effects are bias due to measurement error which is exaggerated by the fixed effects. It is also possible that because prices change so infrequently and sales volatility is such an imperfect predictor of demand uncertainty, that there is even greater attenuation bias in the panel data coefficients. That is, publishers may be very slow to adjust prices to time variation in demand uncertainty, which would significantly reduced the magnitude of the coefficients. I conclude that the cross-section results are the most accurate as they suffer from less measurement error, but it nevertheless is possible that these are in part driven by some other unobserved magazine characteristic which effects the difference in newsstand and subscription prices and is correlated with sales volatility.
References


A Multiplicative Uncertainty

While the primary focus of the paper is to explore whether demand uncertainty is multiplicative or additive, this appendix considers the case in which demand uncertainty is multiplicative in more detail in order to better motivate the difference in difference methodology, and to justify the use of the coefficient of variation as a measure of demand uncertainty.

Assume demand is isoelastic. Demand for subscriptions is known, so \( D(p_{\text{sub}}, \nu) = \nu p_{\text{sub}}^\eta \), where \( \nu \) represents the size of the subscription market, where \( \eta \) is the elasticity of demand, and where \( p_{\text{sub}} \) is the retail subscription price per issue.

Demand for magazines at the newsstand is uncertain, and the uncertainty is multiplicative with the same elasticity of demand as for subscriptions, so the demand function is \( D(p_{\text{sc}}, \epsilon) = \epsilon p_{\text{sc}}^\eta \), where \( \epsilon \) is random and represents the size of the newsstand markets, and where \( p_{\text{sc}} \) is the retail newsstand price. I assume the random variable \( \epsilon \) has a known probability distribution function \( f(\epsilon) \) on \([\epsilon_L, \epsilon_H]\).

In the subscription market, the supply chain’s profit per issue (e.g., per week if the magazine is printed weekly) is

\[
\Pi_{\text{sub}}(p) = (p_{\text{sub}} - c_{\text{sub}}) \nu p_{\text{sub}}^\eta,
\]

where \( c_{\text{sub}} \) is the marginal cost of printing and delivering a single issue of the magazine to the subscription customer through the mail.

Differentiating the supply chain’s profit function with respect to price, the first-order condition is

\[
\nu p_{\text{sub}}^\eta + (p_{\text{sub}} - c_{\text{sub}}) \nu \eta p_{\text{sub}}^{\eta - 1} = 0,
\]

and it follows that the optimal price in the subscription market is

\[
p_{\text{sub}} = \frac{\eta}{1 + \eta} c_{\text{sub}}. \tag{A1}
\]

I assume \( \eta < -1 \), so that \( p_{\text{sub}} \) is well defined.

In the newsstand market, the profit per issue as a function of price and inventory is

\[
\Pi_{\text{sc}}(p, q) = \int_{\epsilon_L}^{\epsilon_H} p_{\text{sc}} \epsilon^\eta f(\epsilon) d\epsilon + p_{\text{sc}} q \left( 1 - F\left( \frac{q}{p_{\text{sc}}} \right) \right) - c_{\text{sc}} q,
\]

where \( q/p_{\text{sc}}^\eta \) is the largest value of \( \epsilon \) for which the inventory is adequate to meet demand.
Let \( z = q/p_{sc} \) denote the stocking factor. So the expected profit function becomes

\[
\Pi_{sc}(p_{sc}, z) = p_{sc}^{\eta+1}\mathbb{E}[\min\{\epsilon, z\}] - c_{sc}zp_{sc}^\eta,
\]

where

\[
\mathbb{E}[\min\{\epsilon, z\}] = \int_{\epsilon_L}^{z} \epsilon f(\epsilon) d\epsilon + z \left(1 - F(z)\right).
\]

The first-order conditions are

\[
(1 + \eta)p_{sc}^{\eta}\mathbb{E}[\min\{\epsilon, z\}] - c_{sc}\eta p_{sc}^{\eta-1}z = 0
\]

and

\[
p_{sc}^{\eta+1}(1 - F(z)) - c_{sc}p_{sc}^\eta = 0.
\]

The first first-order condition can be rewritten as

\[
p_{sc} = \frac{\eta}{1 + \eta E[\min\{\epsilon, z\}]} c_{sc}, \quad (A2)
\]

and the second first-order condition can be rewritten as \((1 - F(z))p_{sc} = c_{sc}\), or

\[
F(z) = \frac{p_{sc} - c_{sc}}{p_{sc}}. \quad (A3)
\]

Taking the log of both sides of equation (A1) yields

\[
\ln p_{sub} = \ln \eta - \ln(1 + \eta) + \ln c_{sub}. \quad (A4)
\]

Taking the log of both sides of equation (A2) yields

\[
\ln p_{sc} = \ln \eta - \ln(1 + \eta) + \ln \frac{z}{E[\min\{\epsilon, z\}]} + \ln c_{sc}. \quad (A5)
\]

Equation (A5) suggests a positive relationship between the newsstand price and demand uncertainty. However without data on the elasticity of demand, \( \eta \), or in costs, \( c_{sc} \), across magazines, estimates of this relationship might be subject to omitted variable bias (specifically, if \( \eta \) and uncertainty are correlated). An alternative to estimating equation (A5) is
to estimate the difference between (A5) and (A1), or
\[
\ln p_{sc} - \ln p_{sub} = \ln \frac{z}{E[\min \{\epsilon, z\}]} + \ln c_{sc} - \ln c_{sub},
\tag{A6}
\]
or equivalently
\[
\ln \frac{p_{sc}}{p_{sub}} = \ln \frac{z}{E[\min \{\epsilon, z\}]} + \ln \frac{c_{sc}}{c_{sub}}.
\tag{A7}
\]

In order to more precisely understand relationship between \(E[\min \{\epsilon, z\}]\) and demand uncertainty, suppose \(z\) is equal to \(\mu\), where \(\mu = E[\epsilon]\). That is, I assume that it is optimal for a stockout to occur 50% of the time. From (A3), this is consistent with costs being about 50% of the newsstand price which is very plausible for the industry.

Since the normal distribution is symmetric, if \(z = \mu\) then \(F(\mu) = 1/2\) and so
\[
E[\min \{\epsilon, \mu\}] = \int_{-\infty}^{\mu} x f(x) dx + \frac{1}{2} \mu
\]
or
\[
E[\min \{\epsilon, \mu\}] = \mu - \int_{-\infty}^{\mu} (\mu - x) f(x) dx
\]
or
\[
E[\min \{\epsilon, \mu\}] = \mu - \frac{1}{2} E[|\mu - x|]
\]
where \(E[|\mu - x|]\) is the mean absolute deviation, which for a normal distribution is equal to \(\sqrt{\frac{2}{\pi}} \sigma\), where \(\sigma\) is the standard deviation of \(z\). So
\[
E[\min \{\epsilon, \mu\}] = \mu - \frac{1}{2} \sqrt{\frac{2}{\pi}} \sigma,
\]
and so
\[
\frac{z}{E[\min \{\epsilon, \mu\}]} = \frac{\mu}{E[\min \{\epsilon, \mu\}]} = \frac{1}{1 - \frac{\sigma}{\mu} \frac{1}{2} \sqrt{\frac{2}{\pi}}},
\tag{A8}
\]
So the difference in the log of the two prices is an increasing function of \(\sigma/\mu\), which is the coefficient of variation. This underscores the need to control for differences in expected sales, \(\mu\), and the appropriateness of doing so by using the coefficient of variation as the measure of volatility.
B Newsvendor Model with Advertising Revenue

Magazine publishers earn revenue through both the market price of magazines and through advertising. The advertising rate is fixed and does not vary with sales, but the rate increases with average circulation, or more precisely, with the magazine’s rate base, a guaranteed circulation that is computed by the Alliance for Audited Media. So some portion of advertising revenues are probably treated as variable by publishers. I assume that the advertising revenue is the same per issue for subscription and newsstand sales and let $a$ denote the advertisement revenue per issue sold.

Magazine publisher’s costs consist of content creation, sales and marketing, and layout, the vast majority of which are fixed costs, and printing and shipping, the majority of which are variable costs.

In the subscription market, the profit function is

$$\Pi_{sub}(p) = (p_{sub} + a - c_{sub})\nu p_{sub}^\eta,$$

where $c_{sub}$ is the marginal cost of printing and delivering a single issue of the magazine to the subscription customer through the mail.

Differentiating the profit function with respect to price, the first-order condition is

$$\nu p_{sub}^\eta + (p_{sub} + a - c_{sub})\nu \eta p_{sub}^{\eta-1} = 0,$$

or

$$\nu (1 + \eta) p_{sub}^\eta + (a - c_{sub})\nu \eta p_{sub}^{\eta-1} = 0,$$

so it follows that the optimal price in the subscription market is

$$p_{sub} = \frac{\eta}{1 + \eta} (c_{sub} - a).$$

I assume $a < c_{sub}$ and $\eta < -1$, so that $p_{sub}$ is well defined.

In the newsstand market, the demand is $\epsilon p^\eta$, so the profit as a function of its inventory, $q$, and price, $p$, is

$$\int_{\epsilon_L}^{q/p_{sc}} (p_{sc} + a) \epsilon p_{sc}^\eta f(\epsilon) d\epsilon + (p_{sc} + a)q \left(1 - F\left(\frac{q}{p_{sc}}\right)\right) - c_{sc}q,$$
where \( q/p^n \) is the largest value of \( \epsilon \) for which the inventory, \( q \), is adequate to meet demand (i.e., \( q = \epsilon p^n \)), and where \( c_{sc} \) is the marginal cost of printing and delivering a single copy of the magazine to the newsstand, whether or not it is sold.

Letting \( z = q/p^n \), the newsstand expected profit function becomes

\[
\Pi_{sc}(p_{sc}, z) = (p_{sc} + a)p^n_{sc}\mathbb{E}[\min\{\epsilon, z\}] - c_{sc}z p^n_{sc},
\]

where

\[
\mathbb{E}[\min\{\epsilon, z\}] = \int_{\epsilon_L}^{z} \epsilon f(\epsilon)d\epsilon + z(1 - F(z)).
\]

The two first-order condition are

\[
(p^n_{sc} + (p_{sc} + a)\eta p^n_{sc}^{-1}) \mathbb{E}[\min\{\epsilon, z\}] - c_{sc}\eta p^n_{sc}^{-1}z = 0,
\]

and

\[
(p_{sc} + a)p^n_{sc}(1 - F(z)) - c_{sc}p^n_{sc} = 0.
\]

The first first-order condition can be rewritten as

\[
((1 + \eta)p^n_{sc} + a\eta p^n_{sc}^{-1}) \mathbb{E}[\min\{\epsilon, z\}] - c_{sc}\eta z = 0
\]

or

\[
((1 + \eta)p_{sc} + a) \mathbb{E}[\min\{\epsilon, z\}] - c_{sc}\eta z = 0
\]

or

\[
p_{sc} = \frac{\eta}{1 + \eta} \left[ \frac{z}{\mathbb{E}[\min\{\epsilon, z\}]} c_{sc} - a \right].
\]

and the second first-order condition can be rewritten as

\[
(p_{sc} + a)(1 - F(z)) = c_{sc}.
\]

or

\[
F(z) = \frac{p_{sc} + a - c_{sc}}{p_{sc} + a}.
\]

The analysis shows that advertising revenue is like a cost reduction with respect to price setting, but is more like a price increase with respect to choosing the optimal stocking factor. That is both prices are lower (and for multiplicative demand uncertainty, they fall
by the same amount so the difference is unchanged), and the stocking factor for single copy sales is higher.

So, under multiplicative demand uncertainty, since the difference in prices is independent of $a$, ignoring advertising differences should not introduce bias, even if advertising differences are correlated with demand uncertainty. But more generally, ignoring advertising could introduce some bias, particularly if changes over time in advertising revenue are correlated with changes over time in demand uncertainty.