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Price Uncertainty and Output Concentration

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Abstract. This paper conducts an empirical investigation to assess the impact of price uncertainty on industry output concentration. Results show that greater price uncertainty leads to greater output concentration; the result is robust to controls for technological factors, barriers to entry effects and other industry controls. The empirical results are consistent with theory which shows that depending on firms attitudes towards risk, output concentration is likely to be endogenous to price uncertainty. Our empirical finding suggests that examining the magnitude of uncertainty could be a useful additional criteria in antitrust policymaking.

Key words: Price uncertainty, industry concentration, antitrust policy.

I. Introduction

The potential endogeneity of industry output concentration to price uncertainty is well established in theory. Theory (Baron (1970), Sandmo (1971), Leland (1972), Hartman (1976) and Appelbaum and Katz (1986), among others) shows that depending on firms' attitudes towards risk, the presence of price uncertainty will alter firm's output levels. The basic result is that under price uncertainty, a risk-averse firm's output level will be lower than a risk-neutral firm's, ceteris paribus. Given that attitudes towards risk are likely to vary across firms, the industry distribution of output will be affected by price uncertainty. Sandmo, for example, concludes that the distribution of output among firms in an industry, and industry output concentration, will depend on the degree and distribution of risk aversion. A clear implication from theory is that price uncertainty is likely to be an important determinant of industry output concentration. In Section II, I present a brief overview of the theoretical results.

In spite of the significance of phenomenon under consideration, there does not appear to have been any empirical evaluation of the impact of price uncertainty on industry output concentration. An empirical examination may provide insights into firms' attitudes towards risk. Further, if price uncertainty emerges as an important determinant of the industry output concentration, it will be policy relevant. The antitrust policy guidelines are in part market structure-based (see Salop, 1987, White, 1987, and the 1992 DoJ and FTC merger guidelines). If industry concentration emerges as being endogenous to price uncertainty, it could be a useful additional criteria in formulating antitrust policy guidelines. I return to this in Section VII.

This paper conducts an exploratory empirical investigation to assess the impact of price uncertainty on industry output concentration by using data for a cross-section of U.S. manufacturing industries. Data on industry product price and input costs are used to construct industry-specific measures of price uncertainty. Section IV contains details regarding measurement of price uncertainty. The empirical results in Section VI show that greater price uncertainty causes industry output concentration to *increase*. This effect is robust to controls for technological scale economies, barriers to entry variables, industry product diversification and a variety of other controls.

II. Role of Price Uncertainty

The theoretical literature examining the impact of price uncertainty on firms' output decisions is voluminous.[1] I indicate the main results relevant for this paper. Consider a price-taking competitive firm producing a homogenous good q. Let $q = f(z)$ be the production function, where q is output and z is the input vector. Profits $\pi = \{pf(z) - c'z\}$, where p is product price and c is the input-price vector. Product price p is stochastic and distributed as $p \sim (\mu, \sigma)$. An increase in price uncertainty is conceptualized by an increase in the standard deviation σ with the expected price μ held constant (a mean-preserving spread in price). We can examine the impact of price uncertainty under alternate scenarios regarding risk preferences. A risk-averse firm maximizes the expected utility U of profits $EU(\pi)$ where $U'(\pi) > 0$ and $U''(\pi) < 0$, whereas the risk-neutral firm maximizes expected profits $E(\pi)$.

We get some standard results. Under price uncertainty,[2] a firm's output level is a *decreasing* function of its degree of risk-aversion.[3] Comparing a risk-averse firm to a risk-neutral firm, the supply function of the risk-averse firm is to the left of the risk-neutral firm's, ceteris paribus.[4]

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[1] Baron (1970), Sandmo (1971), Leland (1972) contain most of the theoretical results comparing a risk-neutral firm's decisions to a risk-averse firm's, ceteris paribus. See Appelbaum and Katz (1986) and Davis (1989) for some additional insights.

[2] Certainty is characterized by the situation where price is known to equal its expected value μ. A risk-neutral firm's analysis is therefore analogous to the deterministic case.

[3] The difference arises because a risk-averse firm, in contrast to a risk-neutral firm, will require a risk premium to compensate for its loss of utility under price uncertainty.

[4] The difference between a risk averse firm's supply function and a risk neutral firm's is an increasing function of the degree of risk aversion. These results were first derived by Baron and subsequently confirmed by Sandmo and Leland. The summary presented here only indicates the broad outcomes. The theoretical models examine variety of factors related to: (i) additive v. multiplicative forms of price uncertainty, (ii) ex-ante v. ex-post decisions regarding output and input choices, (iii) assumptions regarding absolute and/or relative risk aversion, and (iv) the non-linear nature of technology. The literature is too expansive to be summarized here. For our purpose it is sufficient to note that under price uncertainty a risk-averse firm's output will be lower than a risk-neutral firm's, ceteris paribus.

The models cited above assume that all firms within an industry have identical preferences (either risk-neutral or risk averse). This of course is unrealistic. It seems more realistic to assume that there is a "distribution" of attitudes towards risk. If this is true then, under price uncertainty, the distribution of output among firms in an industry, and therefore industry output concentration, will depend on the distribution of risk preferences. This notion is elucidated by Sandmo. [5] Examining the long-run equilibrium under price uncertainty, Sandmo (p.72) concludes:

> In general, the distribution of output among firms will vary with their degree of risk aversion ... those firms which come very close to being risk-neutral (will) have the highest output in the industry ... An uneven distribution of risk aversion may therefore be a source of oligopolistic concentration in its own right.

To summarize, the impact of price uncertainty on industry output concentration will depend on the distribution of risk preferences, ceteris paribus. If all firms were risk-neutral, price uncertainty should not alter industry output concentration. However, under a distribution of risk preferences, with firms varying from being risk-neutral to highly risk-averse, price uncertainty is likely to emerge an important determinant of output concentration. [6]

This hypothesis lends itself to empirical testing. [7] Denoting industry output concentration by CONC, we get:

$$\text{CONC}_i = f(\sigma_i, X_i) \tag{1}$$

where "i" is the industry subscript and σ_i measures industry-specific price uncertainty. An estimate of σ_i is obtained from estimating industry price equations. This is discussed in Section IV. X_i is a vector containing the other determinants of industry output concentration related to technology and barriers to entry. I discuss the components of X_i in the next section.

[5] This notion has been explored elsewhere. In quite a different model, Kihlstrom and Laffont (1979) construct a theory of competitive general equilibrium under uncertainty. In their framework less (more) risk-averse entrepreneurs operate larger (smaller) sized firms.

[6] In my discussion I have emphasized the price uncertainty-risk preference linkage to obtain broad implications for industry output concentration – the focus of Sandmo's paper. There are other aspects of the impact of uncertainty which are not examined in this paper. Mills and Schumann (1985), for example, show that firms' choice of technology is, in part, endogenous to the degree of uncertainty. In the Mills-Schumann framework "smaller" firms choose more flexible low capital-intensive techniques, whereas the "larger" firms choose more capital-intensive techniques. This line of inquiry can be traced back to the paper by Hartman (1976), and some earlier work, who showed that firms' input choices (capital and labor) are, in part, endogenous to the degree of price uncertainty. Ghosal (1995) finds that greater price uncertainty is associated with higher capital-labor ratios. In short, there are various aspects of the impact of price uncertainty that are not explored here. My objective in this paper is to examine the broad relationship between price uncertainty and output concentration.

[7] Since we cannot observe firms' attitudes towards risk, this fundamental behavioral parameter remains an unobservable. We can empirically examine the relationship between price uncertainty and output concentration and then draw inferences regarding the nature of risk preferences.

Regarding industry output concentration CONC, any well defined measure of output concentration would suffice for our purposes. I use two common measures of output concentration:

(i) The industry Herfindahl-Hirschmann Index HHI.

(ii) The industry four-firm concentration ratio CR4.

Both these measures have been widely used in empirical industrial organization studies and antitrust policy guidelines. [8]

1. Theory to Empirics: Sample Selection Issues

The theoretical models make three important assumptions:

(A) *Competitive* product markets. To mimic this market condition we need to segment our sample into a relatively competitive group of industries. For this we need a measure of market power. There appears to be two options:

(i) Use the methodology outlined in Appelbaum (1982) to obtain estimates of the degree of oligopoly power and use this measure to segment our sample. Appelbaum's framework involves estimating a 5-equation simultaneous equations system for each industry. [9] While pursuing this strategy would constitute a rigorous way of delineating industries, our industry data base does not contain enough time-series observations per industry to estimate the simultaneous equations system outlined in Appelbaum.

(ii) Resort to the use of industry concentration indexes, CR4 for example, to segment the industries into a relatively competitive group. [10]

In particular, I use CR4 values of 0.37 and 0.20 to construct "relatively" competitive samples. It appears unlikely that in industries with such low CR4 there will be significant market power. I return to a more detailed discussion of this issue in Section III.

Creating relatively competitive sub-samples has an added advantage. The price uncertainty measure σ_i could be potentially endogenous to industry output concentration $CONC_i$. Estimation within a relatively competitive group of industries circumvents this potential inference problem.

(B) The industry is characterized by a *single-product*. However, firms in most broadly defined industries produce multiple products. As will be discussed in Section III, I use a measure of the degree of industry product diversification to segment industries.

[8] The HHI results, for example, may be of particular interest as the Department of Justice and the Federal Trade Commission has increasingly used this measure to evaluate the likelihood of non-competitive behavior (see Salop (1987), White (1987) and section 1.5 of the 1992 DoJ and FTC guidelines).

[9] The 5-equation system consists of 3 factor demand equations (labor, capital and materials), an output supply equation and the price equation. The system has 16 free parameters and is estimated by full-information maximum likelihood (see p.295).

[10] It is of course widely known that industry CR4 has limitations as an index of oligopoly power.

Imposing controls for product diversification and product market competition will bring our sample closer to the structural characteristics cited in theory.

(C) All firms in the industry face the same degree of price uncertainty. The direct way to address this issue would be to use firm-level time-series data and construct the price uncertainty measure at the firm level, and then examine firm-specific as well as industry-wide effects. However, to the best of my knowledge, no consistent firm-level time-series data set is available for a large number of industries. [11]

There appears to be another way of addressing this issue. If the industry structure is reasonably atomistic, large number of firms and low CR4, it would appear meaningful to argue that the industry-wide price uncertainty is a reasonable proxy for price uncertainty facing all firms within the industry. [12] I return to this issue, along with the sample selection issue raised by assumption (A), in Section III.

III. Empirical Model

My objective here is not to test any structural hypothesis but merely to examine the broad impact of price uncertainty on industry output concentration. I therefore use a fairly standard empirical model of industry concentration within which I measure the impact of price uncertainty. [13] All variables in (2), excluding GROWTH, are measured in *logarithms*. [14] Appendix 2 contains the variable definitions.

$$\begin{aligned}\mathrm{HHI}_i = {} & \alpha_0 + \alpha_1\sigma_i + \alpha_2\mathrm{MES}_i + \alpha_3\mathrm{ADVT}_i + \alpha_4\mathrm{GROWTH}_i + \alpha_5\mathrm{DEPR}_i \\ & + \alpha_6\mathrm{USED}_i + \alpha_7\mathrm{RENTAL}_i + \varepsilon_i \qquad (2)\end{aligned}$$

where HHI is the industry Herfindahl-Hirschmann Index and σ is a measure of price uncertainty. I also present results using the four-firm concentration ratio CR4

[11] One could potentially use firm-level data from the COMPUSTAT but due to the definition of the "firm" in this data base it is not particularly suitable for my analysis. For example, firms are defined as financial entities and the multiproduct nature of firms becomes a serious problem.

[12] This is motivated by the logic that if the size distribution of firms within an industry is highly skewed with the industry having very large as well as very small firms, the price movements and therefore the degree of price uncertainty facing the smaller firms may well be different from that facing the larger firms. However, this is less likely if the industry structure is one of a "large number of small-sized firms."

[13] The variables used below have been used in other empirical industry structure studies. See Kessides (1990), Curry and George (1983) and the references contained there. I should point out that all these studies use CR4 as the measure of output concentration; I use both the HHI and CR4. When examining industry structure, ideally there should be a control for industry demand. However, I'm not aware of any variable that measures pure industry demand. Bresnahan and Reiss (1991), in a study of local markets, use local demographic variables to control for demand. It does not appear that such measures could be constructed for the industries in our sample.

[14] Estimating industry structure equations in logarithmic form is standard practice. See Kessides (1990) and Curry and George (1983). GROWTH is not in logarithms as some industries have negative values for GROWTH. Estimating the equation in logarithmic form also enables us to interpret the coefficient estimates as elasticities.

as the dependent variable. Construction of σ is described in Section IV. MES measures scale economies. Following Kessides (1990), I include three proxies of sunk costs; DEPR, USED and RENTAL. From the contestable markets literature, entry barriers are likely to be lower (low sunk costs)[15] if a large proportion of capital can be rented or bought as used capital, or if capital depreciates rapidly. From the variable definitions (see data Appendix 2), increase in DEPR and RENTAL signify higher barriers (α_5, $\alpha_7 > 0$) and increase in USED indicates lower barriers ($\alpha_6 < 0$). Lastly, advertizing intensity, ADVT, and industry sales growth, GROWTH, are included as additional controls for entry conditions.

1. Time Period for Variables in Equation (2)

(i) The variables HHI, CR4, MES, DEPR, USED, RENTAL and ADVT are from the 1982 Census of Manufactures. I choose this Census year as data on industry HHI were published for the first time in the 1982 Census.

(ii) The price uncertainty measure σ will be constructed by estimating industry price equations over a period *preceding* and up to the 1982 Census year. This is designed to avoid inference problems which may arise due to the potential endogeneity of σ to HHI (or CR4). In particular, I estimate industry price equations over the period 1967–1982 to construct σ. I return to this in Section IV.

(iii) GROWTH is the average annual growth of real industry sales over the period 1967–82.

2. Sample Selection

2.1. Product diversification

I control for product diversity in two ways. First, all "miscellaneous" industries were excluded as many different product categories are lumped into these groupings. Second, I use the industry Primary Product Specialization Ratio (PPSR) as a proxy for product diversity. PPSR measures the extent to which plants classified in a SIC 4-digit industry specialize in making products "primary" to that industry. Industries with low PPSR (greater product heterogeneity) were excluded. For the 1982 Census year, the mean PPSR across industries is 91%; I use this as the cutoff. All industries with PPSR $\leq$ 91% were excluded from the sample. [16]

2.2. Competitive product markets

I create three "relatively" competitive sub-samples:

[15] For the role of sunk costs see Baumol, Panzar and Willig (1982) and Sutton (1991). See Shepherd (1984) for insightful comments on the Baumol *et al.* hypothesis.

[16] The industry PPSR appears to be the only available proxy for product diversification.

TABLE I. CR4 Summary Statistics

	Mean	Std. Dev.	Min.	Max.
Sample 1: No Control for CR4, n = 112				
CR4(1967)	0.3520	0.2044	0.04	0.94
CR4(1982)	0.3562	0.1964	0.06	0.85
Sample 2: CR4(1967) $\leq$ 0.35, n = 66				
CR4(1967)	0.2056	0.0895	0.04	0.35
CR4(1982)	0.2309	0.1107	0.06	0.58
Sample 3: CR4(1967) and CR4(1982) $\leq$ 0.35, n = 59				
CR4(1967)	0.1973	0.0891	0.04	0.35
CR4(1982)	0.2041	0.0796	0.06	0.35
Sample 4: CR4(1967) and CR4(1982) $\leq$ 0.20, n = 21				
CR4(1967)	0.1157	0.0567	0.04	0.20
CR4(1982)	0.1195	0.0476	0.06	0.20

(i) Use data on CR4 from the 1967 Census year to segment the sample. [17] For the 1967 Census year the cross-industry mean value of CR4 is 0.352 with a standard deviation of 0.20. The top panel of Table I presents the summary statistics for CR4 for 1967 and 1982. There is no "standard" demarcation of competitive v. noncompetitive industries based on industry CR4 values. Domowitz *et al.* (1987) use CR4 = 0.50 to segment the sample. White (1987, p.17) implies a range of CR4 between 0.50–0.60. Results in Ghosal (1989) show the cutoff to be around CR4 $\approx$ 0.55. Given these numbers, a CR4 value of 0.35 (the cross-industry mean) appears to be a safe cutoff. I exclude industries which had (the 1967) CR4 $>$ 0.35.

(ii) The second panel in Table I shows that there are some industries which had low CR4(1967) but over time their concentration has increased as evidenced by the maximum CR4(1982) = 0.58. I created a second sub-sample with CR4(1967) *and* CR4(1982) $\leq$ 0.35. This sub-sample contains industries with low CR4

[17] Given that CR4 will be a dependent variable in equation (2), segmenting by 1982 CR4 data only may create inference problems as such a segmentation would preclude conditional normality. Segmenting the sample using 1967 CR4 avoids any obvious endogeneity problems.

TABLE II. Industry Structure Characteristics: Sample 3

Variable	Mean	Std. Dev.	Min.	Max.
HHI	215	131	18	487
CR4	0.2041	0.0796	0.06	0.35
FIRMS	1664	2872	86	17332
PPSR	95	2.31	91	100

The variables above are for the Census year 1982.

over the entire sample period over which the price uncertainty measure is constructed.

(iii) I use the mean CR4 value of 0.20 from panel 3 and create another sub-sample which contains industries with CR4(1967) and CR4(1982) $\leq$ 0.20.

2.3. *Sample summary*

I present estimates for four samples. All samples exclude miscellaneous and low PPSR industries.

Sample 1: The full sample of industries which imposes no controls for CR4; sample size n = 112 industries.

Sample 2: Industries with CR4(1967) $\leq$ 0.37, n = 66.

Sample 3: Industries with CR4(1967 and 1982) $\leq$ 0.37, n = 59.

Sample 4: Industries with CR4(1967 and 1982) $\leq$ 0.20, n = 21.

Clearly, Sample 4 has a small number of observations and drawing substantive conclusions from this sample results may be hazardous. I present estimates from this sample merely to check the robustness of our earlier sample results.

3. Firm Versus Industry Price Movements

Table II presents a broad picture of the industry structure characteristics from SAMPLE 3. The "representative" industry in this sample has CR4 = 0.20, HHI = 215, 1664 firms and 95% of the industry's products are specific to the industry classification. Compare the above numbers to what appear to be the cutoffs for CR4 and HHI in the antitrust literature: CR4 between 0.50–0.60, and HHI between 1,000–1,600 (White, p.16–18). Based on CR4 = 0.20, the average top-four firm has a market share of 5%. Based on an HHI = 215 for the top 50 firms, an average top-fifty firm has about 2% market share. These market shares appear too small to produce any significant market power. The structure appears quite atomistic; SAMPLE 4 takes this to an even greater extreme. It does not appear far fetched to argue that in such an atomistic industry the industry-wide measure of price uncertainty is a reasonable proxy for uncertainty facing "all" firms. [18] The overall characteristics of this sample appear to closely resemble the structural characteristics cited in theory.

IV. Measuring Price Uncertainty

The strategy adopted here is to assume that industry price follows a process and firms are able to observe this "price-process." To the extent that price is forecastable, this reduces the uncertainty that they face. The conditional standard deviation of this price-process therefore measures price uncertainty. [19] I discuss construction of two measures of price uncertainty below. Some alternate measures are discussed in Section V.

1. Measure 1

The first measure of price uncertainty is constructed by using a partial-price adjustment model to derive the price equation. Details of the derivation, variable transformations and other econometric issues are contained in Appendix 1 (Equation (A.1)). [20]

$$p_{it} = \beta_0 + \beta_1 p_{it-1} + \beta_2 avc_{it-1} + \beta_3 avc_{it-2} + u_{it} \qquad (3)$$

where $u_{it} \sim (0, \sigma(u_i)^2)$. As discussed in Appendix 1, p_{it} is the *growth rate* of industry relative (deflated by the GNP deflator) product price [21] and avc_{it} is the growth rate of industry relative variable cost per unit (the sum of unit wage, materials and energy costs). I consider an alternate cost index in Section VI.

Equation (3) is a fairly general price equation as it captures dynamics in prices and costs via one lag of price p_{it-1} and two lags of unit cost avc_{it-1} and avc_{it-2}. As indicated in Appendix 1, the lagged price p_{it-1} also controls for persistence in prices that may arise due to various price "inflexibility" arguments. As I discuss in Section V, our results are not sensitive to the inclusion of additional lags. However,

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[18] Essentially in such an atomistic industry no firm is likely to be able to influence price movements due to the lack of significant market power.

[19] The notion of measuring uncertainty about a variable as the conditional standard deviation of that variable is consistent with the theoretical and empirical quantification of uncertainty. In the literature on investment under price uncertainty for example (Pindyck, 1982; Huizinga, 1993; and Ghosal and Loungani, 1994; among others), "price" uncertainty is measured as the conditional standard deviation. In Ghosal (1991) "sales" uncertainty is similarly measured. Also, see Zarnowitz and Lambros (1987) for a general discussion of economic prediction and the measurement of uncertainty.

[20] This specification is similar to that in Ghosal (1995).

[21] A comment about our industry price measure is in order. The industry price data used is an industry price index (similar to the Producer Price Index in manufacturing). Ideally one would like to use transactions prices to measure price uncertainty. However, such a data base is not available. Weiss (1977) examined the correlation between *changes* in transactions prices (for a limited set of industries) and the industry price deflator (like the one used here) and found the two series to be highly correlated. He concluded that the two series (p. 619) "...do not differ importantly." This implies that examining growth rates in prices will provide meaningful price change information.

the degrees of freedom vanish rapidly given the relatively small number of time-series observations. Lastly, since equation (3) is in growth rates, the constant term β_0 allows industry relative price to drift over time. This captures additional deterministic components not accounted for by the included explanatory variables.

I estimated equation (3) for *each* industry over the period 1967–1982. In general, the industry price regressions had a good fit. The mean values (across industries) of the coefficient estimates were $\beta_1 = 0.22$, $\beta_2 = -0.08$ and $\beta_3 = -0.11$. The standard deviation of the estimated residuals from (3) is the first measure of price uncertainty, $\sigma(u_i)$. I present some summary statistics in Section V.

2. Measure 2

The second price equation used is a univariate, second-order, autoregressive model to fit the growth rate of industry relative product price.[22]

$$p_{it} = \zeta_0 + \zeta_1 p_{it-1} + \zeta_2 p_{it-2} + e_{it} \tag{4}$$

where $e_{it} \sim (0, \sigma(e_i)^2)$. Univariate autoregressive specifications, for example, are common in studies examining the effects of inflation uncertainty (see Huizinga and the references contained there). I estimated equation (4) for each industry over the period 1967–1982. The standard deviation of the estimated residuals from (4) is the second measure of price uncertainty, $\sigma(e_i)$.

3. Potential Endogeneity of σ

Price movements are likely to be endogenous to industry concentration. Empirical results in Domowitz, Hubbard and Petersen (1987), for example, show that the time-series behavior of prices in highly concentrated industries appear to be different from low concentration industries. If σ is endogenous industry concentration, OLS estimation will yield inconsistent parameter estimate of α_1 (equation (2)). This potential endogeneity problem in controlled in two ways:

(i) Segment the sample into a relatively competitive group of industries. This was discussed in the previous section (construction of Samples 2, 3 and 4). Endogeneity is unlikely to be a problem in such relatively competitive samples.

(ii) In equation (2), HHI is for the year 1982 whereas σ is constructed using data over a preceeding period 1967–1982. This again is designed to minimize endogeneity problems.

As it turns out, our qualitative conclusions are similar across the various samples.

[22] This specification is similar to that used by Huizinga (1993, p. 541–544), although his detrending scheme is different.

TABLE III. Summary Statistics: Sample 1, n = 112

Variable	Mean	Std. Dev.	CV[a]	Min.	Max.
HHI	609	554	91	18	2214
CR4	0.3562	0.1964	55	0.0600	0.8500
$\sigma(u)$	0.0463	0.0396	86	0.0087	0.2749
$\sigma(e)$	0.0479	0.0404	84	0.0101	0.2874
MES	0.0114	0.0147	129	0.0011	0.1318
DEPR	0.9266	0.0170	2	0.8760	0.9640
USED	0.0818	0.0563	69	0.0033	0.2857
RENTAL	0.9578	0.0442	5	0.7463	0.9990
ADVT	0.0152	0.0259	170	0.0005	0.1972
GROWTH	0.0122	0.0334	274	−0.066	0.1766

Coefficient of variation (percent).

V. Data Characteristics

An important question is whether there is significant variation in price uncertainty across industries. This is clearly important from the viewpoint of our proposed cross-industry investigation of the relationship between price uncertainty and output concentration. Table III presents summary statistics for the full sample of industries.

Focussing on the uncertainty measures several observations emerge. First, the values of $\sigma(u)$ range from a low of 0.0087 to a high of 0.27 with a 85% coefficient of variation. This represents a wide variation in price uncertainty across industries. Similar observations emerge for $\sigma(e)$. Second, the two measures of price uncertainty appear to have similar distributional characteristics as evidenced by the mean values and standard deviation. Thus, not much information is gained by going from price equation (3) to (4) and vice versa. This is probably not very surprising as the lagged values of p_{it} capture a significant amount of deterministic changes in demand and costs. Regarding output concentration, summary statistics show large cross-industry variation in both HHI and CR4. In short, our sample contains substantial variation in these key variables which is encouraging from the viewpoint of our cross-industry analysis. [23]

VI. Results

Results using HHI as the measure of output concentration are presented in Table IV. Column 1 presents the full sample results. The regression statistics show that close to two-thirds of the cross-industry variation in HHI is explained by our set

[23] As an issue tangential to the main focus of this paper, the sunk cost proxies related to DEPR and RENTAL have very little cross-industry variation. There is more variation in USED across industries.

TABLE IV. Estimation Results. Dependent Variable: HHI

	Sample 1	Sample 2	Sample 3	Sample 4
$\sigma(u)$	0.279	0.324	0.392	0.862
	(0.093)	(0.139)	(0.150)	(0.164)
MES	0.758	0.844	0.760	1.159
	(0.086)	(0.151)	(0.161)	(0.199)
ADVT	0.107	0.117	0.105	0.262
	(0.053)	(0.086)	(0.094)	(0.129)
GROWTH	5.81	4.52	5.65	8.53
	(1.76)	(3.57)	(3.61)	(4.59)
DEPR	12.34	3.95	3.12	−5.57
	(4.43)	(7.39)	(7.91)	(12.4)
USED	−0.217	−0.247	−0.199	−0.137
	(0.064)	(0.109)	(0.137)	(0.145)
RENTAL	2.70	1.72	1.53	2.65
	(1.46)	(1.61)	(2.07)	(2.13)
Adj-R^2	0.6503	0.5359	0.4235	0.6425

[a]Heteroscedasticity-consistent standard errors are in parentheses. All variables, except GROWTH, are in logarithms. The 1%, 5% and 10% levels of significance for the t-statistic (one-tailed test) are 2.32, 1.64 and 1.28, respectively.
[b]Sample Description:
Sample 1: PPSR $\geq$ 91, no control for CR4, sample size = 112.
Sample 2: PPSR $\geq$ 91, CR4(1967) $\leq$ 0.35, sample size = 66.
Sample 3: PPSR $\geq$ 91, CR4(1967 and 1982) $\leq$ 0.35, sample size = 59.
Sample 4: PPSR $\geq$ 91, CR4(1967 and 1982) $\leq$ 0.20, sample size = 21.

of explanatory variables. The estimate of the $\sigma(u)$ coefficient shows that price uncertainty has a statistically significant positive effect on industry output concentration.

We turn to examining the quantitative effect of price uncertainty in more detail. Given that Equation (2) is estimated in logarithmic form, we can interpret the coefficient estimate (0.28) as the price uncertainty elasticity. From Table III, the cross-industry mean (std. dev) of $\sigma(u)$ is 0.0463 (0.0396). Starting from $\sigma = 0.0463$ and the cross-industry mean value of HHI = 609, a one-standard-deviation increase in $\sigma(u)$ to 0.0859 causes HHI to increase by about 145. This represents a fairly large quantitative effect of price uncertainty.

Comparing the estimate of $\sigma(u)$ from column 1 to columns 2 and 3 we find that the point estimates are only marginally higher. For Sample 3, a one-standard-deviation increase in $\sigma(u)$ causes the HHI to increase by 62. While this quantitative effect is smaller than the full sample, it still represents a meaningful economic

TABLE V. Estimation Results. Dependent Variable: CR4

	Sample 1	Sample 2	Sample 3	Sample 4
$\sigma(u)$	0.160	0.184	0.202	0.451
	(0.051)	(0.072)	(0.081)	(0.091)
MES	0.421	0.456	0.420	0.571
	(0.048)	(0.083)	(0.089)	(0.111)
ADVT	0.065	0.074	0.066	0.129
	(0.031)	(0.047)	(0.053)	(0.072)
GROWTH	3.353	2.613	3.199	4.715
	(1.01)	(1.94)	(1.97)	(2.87)
DEPR	7.203	2.077	0.889	−4.814
	(2.78)	(3.92)	(4.09)	(6.84)
USED	−0.126	−0.151	−0.122	−0.023
	(0.037)	(0.061)	(0.073)	(0.074)
RENTAL	1.571	0.953	1.040	1.984
	(0.791)	(0.871)	(0.914)	(1.19)
Adj-R^2	0.6557	0.5383	0.4164	0.5908

See notes to Table IV.

effect. In contrast to Samples 2 and 3, the estimate of the $\sigma(u)$ effect from Sample 4 is significantly greater. However, caution needs to be exercised in interpreting the results from Sample 4 due to the small number of cross-industry observations. The main point however is that our qualitative conclusions are invariant to the specific sample used; full sample or the relatively competitive samples.

I briefly comment on the results using CR4 as the measure of output concentration. The results are presented in Table V. It is sufficient to note that once again our qualitative conclusions remain invariant to the specific sample used; greater price uncertainty causes industry output concentration to increase.

Since the focus of this paper is on the impact of price uncertainty, I'll make a few comments on the other explanatory variables. The coefficient of MES is significant and positive as expected. The coefficients of the sunk cost proxies, RENTAL, USED and DEPR, and ADVT are all of the expected sign[24] and statistically significant.[25] It is worth noting that the significance levels on the sunk cost proxies and advertizing generally drops as we go from, say, Sample 1 to Sample 3. This is not wholly unexpected as the role of the sunk costs and advertizing related barriers to entry

[24] Other than the sign on the DEPR coefficient in Sample 4.

[25] My sample and the one used by Kessides are not directly comparable as I have imposed many restrictions to conform to the theoretical specifications. In Kessides, the estimates of DEPR, RENTAL and USED are 5.11, 4.36 and −0.05 (see his Table II). The corresponding estimates in this paper (from Table V and Sample 1) are 7.20, 1.57 and −0.12. Kessides does not use the HHI as a measure of concentration, he only uses CR4.

effects are likely to be diminished in a highly competitive sample industries. Once again, I refrain from drawing any substantive conclusions based on Sample 4 coefficients and significance levels due to the small number of observations.

1. RESULTS USING $\sigma(e)$

Very similar estimates were obtained using this measure of price uncertainty. For example, the corresponding point estimates (standard errors) using $\sigma(e)$ (and HHI as the concentration measure) were 0.27 (0.09), 0.31 (0.14), 0.36 (0.15) and 0.82 (0.16) for Samples 1 through 4, respectively. None of these estimates are statistically different from those reported in Table IV. This is not surprising given the similar distributional characteristics between $\sigma(u)$ and $\sigma(e)$. Thus our conclusions remain unchanged.

2. MORE MEASURES OF PRICE UNCERTAINTY

I experimented with variations of the price equations (3) and (4) to create alternate measures of price uncertainty. I experimented with different lag lengths. I also created a measure of price uncertainty by replacing the cost measure *avc* by an industry materials and energy price index (*mat*; see data appendix) and reestimated equation (3) to obtain the uncertainty measure. The estimates obtained using these alternate measures were not statistically different from those reported in Table IV.

3. SUMMARY OF EMPIRICAL RESULTS

Our empirical analysis shows that greater price uncertainty leads to greater industry output concentration. This result is robust to (i) alternate measures of industry output concentration, (ii) alternate measures of price uncertainty, and (iii) choice of alternate samples; full sample of industries or relatively competitive samples.

VII. Concluding Remarks and Implications

The empirical finding of a positive effect of price uncertainty on industry output concentration is broadly consistent with the theoretical predictions. Our finding lends credence to the notion that there is a distribution of firms by their attitudes towards risk. This distribution of risk preferences in turn determines the distribution of output levels and output concentration, ceteris paribus. [26]

[26] As indicated earlier in the paper, a useful extension of our industry-wide study would be to examine firm level data. This would allow us to control for firm-level as well as industry-wide effects and contribute additional insights into firm behavior and choice of output levels under price uncertainty. Another useful extension would be to construct a panel data set where we could examine the relationship between "changes" in price uncertainty and output concentration. However, given the relatively small number of time-series observations available per industry, and the fact that the

Our empirical finding of price uncertainty affecting market concentration has potential implications for antitrust policy. [27]

It may be useful to begin with a brief historical perspective. [28] The traditional line of reasoning in formulating antitrust policy tended to equate market concentration (or large firm size) with market power. The Brown Shoe (1962) and Von's Grocery (1966) cases were direct confirmation of this. This traditional view was challenged by Demsetz (1973), and later Peltzmann (1977), who argued that larger firms tended to be more efficient. Under this "efficiency" interpretation of firm size, they concluded that a deconcentration policy would reduce welfare. [29]

Thus Demsetz and Peltzman lead us to examine more closely the "causes" of market concentration and formulate (or reformulate) public policy.

Our empirical analysis, drawing insights from earlier theoretical contributions, shows that industry structure is endogenous to price uncertainty. Given that concentration appears to be the endogenous response to underlying economic uncertainty, concern with market concentration may be misguided. Our results indicate that uncertainty is an important cause of market concentration and, therefore, examining the magnitude of uncertainty may be a useful additional criteria in antitrust policymaking.

Appendix 1

I. Price Equation

I use the partial-adjustment rule to derive the price equation. The partial adjustment rule is derived from a quadratic price adjustment cost model where the firm chooses p_t to minimize expected present discounted value of disequilibrium and adjustment costs. The model predicts small and frequent price changes as firms face costs associated with changing list prices, informing dealers and losing consumer loyalty. The menu cost and (S,s) pricing rules, on the other hand, predict larger and infrequent price changes. There is a price range where there is inertia as firms trade off costs of adjusting prices to disequilibrium costs. Carlton (1986) presents an excellent overview of the causes of price rigidity. He finds evidence of price rigidity in many industries and observes small incremental as well as large infrequent changes.

industry structure data are available once every five years (HHI was published in 1982 for the first time), there appear to be serious data constraints.

[27] The antitrust guidelines (see Section 1.5 of the 1992 DoJ and FTC merger guidelines) use market concentration measured by the HHI, and a variety of other factors, to evaluate the "likelihood" of non-competitive behavior.

[28] Mueller (1993), Mueller and O'Connor (1993) and Shepherd (1993) contain informative discussion of the 1992 merger guidelines and some historical background.

[29] To the extent that successful acquisition of newer technologies were resulting in larger firms, a policy of deconcentration would be clearly detrimental to economic growth and welfare.

Consider the partial price-adjustment rule $(p_{it} - p_{it-1}) = \lambda(p^*_{it} - p_{it-1})$ where p_{it} is the actual price and p^*_{it} the desired price. We can rewrite p_{it} as

$$p_{it} = (1 - \lambda)p_{it-1} + \lambda p^*_{it}$$

The target price p^*_{it} depends on expected demand, D^e_{it}, and costs, C^e_{it}: $p^*_{it} = \theta_0 + \theta_1 C^e_{it} + \theta_2 D^e_{it}$. Unfortunately, there is no variable available to me that measures pure industry demand. Thus, the desired price is expressed as a function of expected costs only:

$$p^*_{it} = \theta_0 + \theta_1 C^e_{it} + \text{error}_{it}$$

and D^e_{it} is subsumed in the error term. Regarding elimination of C^e_{it}, I follow the standard practice of using distributed lags to proxy for the expected value. Thus, after substituting to eliminate the desired target, the price equation is

$$p_{it} = \phi_0 + \phi_1 p_{it-1} + \Sigma_s \eta_s C_{it-s} + \text{error}_{it}$$

The coefficient ϕ_1 embeds the partial-adjustment parameter which allows for persistence in prices.

1. Estimation Issues

(i) An appropriate cost measure is needed to replace C. I use industry variable costs per unit, avc_{it}, to replace C_{it}. It can be shown from short-run profit maximization, and considering discrete changes, that change in price $\Delta p \approx \Delta AVC$.

(ii) Issue of lag length. I assume that AVC follows a second-order autoregressive process, AR(2). This implies that two lags of *avc* enter the price equation. Our ability to include more lags is limited by the relatively few time series observations. However, given that the data are annual, assuming an AR(2) specification is probably not too restrictive.

(iii) As price movements should be industry-specific, industry price and *avc* are deflated by the implicit GNP deflator to obtain relative measures.

(iv) Lastly, as data on prices and costs are likely to be non-stationary, data were transformed into logarithmic first-differences. Hamilton (1994, Ch.15) contains an extensive discussion of deterministic versus stochastic trends. Given the relatively few time-series observations it will be difficult to distinguish between alternate trend specifications.

Incorporating (i)–(iv), our empirical price equation is

$$p_{it} = \beta_0 + \beta_1 p_{it-1} + \beta_2 avc_{it-1} + \beta_3 avc_{it-2} + u_{it} \tag{A.1}$$

where u_{it} is a white noise error with $u_t \sim (0, \sigma^2)$. The constant term β_0 is included to account for the possibility that p_{it} may have a nonzero mean. The constant

β_0, by allowing p_{it} to grow at some nonzero rate over time, provides a control for deterministic components not accounted for by the explanatory variables. For example, due to lack of data equation (A.1) does not control for capital cost. If capital costs are increasing over time then β_0 will capture some of this change.

Appendix 2

II. Data

1. Industry Time-Series Data

The industry time-series data are from the Productivity Database assembled at the NBER. The data set used in this paper contains annual data for SIC 4-digit industries over the period 1967–1982. Data are from various issues of the Census of Manufactures and the Annual Survey of Manufactures.

p = Industry shipments price deflator (1972 = 1.0).

SALES = Real industry shipments (1972 dollars).

AVC = Industry variable cost per unit (sum of unit wage and unit materials plus energy costs).

MAT = Industry materials and energy price index (1972=1.0).

2. Industry Cross-Section Data

Data are for the SIC 4-digit classification from the 1982 Census of Manufactures.

HHI = Herfindahl-Hirschmann Index for the top 50 firms in the industry. HHI = $\Sigma_i(sh_i)^2$ where sh_i is the market share (percent) of the ith firm and $i = 1, \ldots, 50$. For the SIC 4-digit industries, this measure was published for the first time in the 1982 Census.

CR4 = Industry four-firm output concentration ratio.

PPSR = Primary product specialization ratio: value of shipments of primary products of plants in the industry as a ratio of the total shipments of all products made by these establishments.

ADVT = Ratio of advertizing expenditures to industry shipments.

RENTAL = (1 − SHRRENT), where SHRRENT is the ratio of rental payments on plant and equipment to capital stock.

USED = Ratio of expenditures on used plant and equipment to the sum of expenditures on used and new plant and equipment.

DEPR = (1 − SHRDEPR), where SHRDEPR is the ratio of depreciation payments to total stock of depreciable capital.

MES: The MES measure is constructed following Kessides (1990). The proxy for scale economies relative to industry size, MES, is constructed by using the distribution of plants within each industry according to employment size. [30] Let n_j and s_j be the number of plants and total sales of the jth size group. The total

[30] There are well known problems with constructed measures of MES. See Davies (1980).

number of size groups within the industry is m $(j = 1, \ldots, m)$. Let $Ms_j = (s_j/n_j)$ and define $S^* = (1/m)\Sigma_j(Ms_j)$. The total industry sales across all size groups is SALES = $\Sigma_j(s_j)$. Then the proxy for scale economies relative to industry size is MES = (S*/SALES).

FIRMS = Total number of firms in the industry.

3. Omitted Industries

Industries which underwent definition change in 1967, 1972 and 1977 and for which a consistent time series could not be constructed were excluded. Miscellaneous industries were dropped from the sample. Lastly, industries with missing data on any industry structure variable used in this paper were excluded.

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