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Empirical issues in markets and organizations

Output price, markups, and producer size

Mark J. Roberts [a,*], Dylan Supina [b]

[a] Department of Economics, 513 Kern Building, The Pennsylvania State University, University Park, PA 16802, USA

[b] Department of Economics, University of Vienna, Vienna, Austria

Abstract

This paper examines how output prices and markups vary across the size distribution of producers. It uses unique plant-level data on physical output, revenue, and input expenditures for six homogeneous U.S. manufactured products. The results reveal that, for five of the six products, output prices decline systematically with increases in plant size. In the most extreme case, corrugated boxes, the smallest producers have prices that average 20 percent above the mean price while the largest producers average 10 percent below the mean. At the other extreme, the price dispersion for gasoline is small and unrelated to plant size. Plant-specific markups of price over marginal cost vary across the size distribution of producers for five of the products. In three cases they decline, in two cases they increase, and one product, gasoline, shows no systematic variation.

JEL classification: L1; L6

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1. Introduction

Over the last two decades, the empirical focus in industrial organization has steadily shifted from the analysis of across-industry differences to the study of individual markets. As part of this shift, industrial economists have begun to exploit micro cross-section and panel data sets and these explorations have resulted in a better understanding of the diversity among producers. Of particular

* Corresponding author. Tel.: (814) 863-1535; Fax: (814) 863-4775.

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importance in industrial organization are within-industry differences in the economic performance of large and small producers. Differences in profitability, and their persistence over time, have been well-documented by Mueller (1986), Geroski and Jacquemin (1988) and others. Whether these differences arise because large producers are more cost efficient, as suggested by Demsetz (1973), or because large producers are able to charge higher markups on their products is harder to determine. (Empirical evidence is summarized in Schmalensee (1989).) Datasets containing the necessary information on both output prices and production costs for a representative cross-section of producers in a specific output market are rare, often because data on physical output and/or output prices is not collected at the micro level. [1]

In this paper we use unique plant-level data on physical output, revenue, and input expenditures for a number of homogeneous U.S. manufactured products and examine the pattern of output prices and markups across the size distribution of producers. We examine six homogeneous manufactured products: white pan bread, roasted coffee, corrugated boxes, gasoline, ready-mixed concrete, and tinplate steel cans. The results reveal that, for five of the six products, output prices decline systematically with increases in plant size. In the most extreme case, corrugated boxes, the smallest producers have prices that average 20 percent above the mean price while the largest producers average 10 percent below the mean. At the other extreme, the price dispersion for gasoline is small and is unrelated to plant size. Plant-specific markups of price over marginal cost are found to vary across the size distribution of producers for five of the products. In three cases they decline, in two cases they increase, and one product, gasoline, shows no systematic variation.

The next section of this paper discusses some unique characteristics of the plant-level output price data, summarizes the dispersion in output prices across plants, and relates prices to producer size. The third section briefly summarizes the econometric models used to estimate plant-level marginal cost and examines how plant-specific markups vary across the size distribution of producers.

2. Output price variation in census establishment data

As part of the quinquennial U.S. *Census of Manufactures* establishments are asked to report the value of shipments of each seven-digit SIC product they manufacture as well as the physical quantity they produce for a subset of products

[1] There have been several empirical studies of output price dispersion, many of which are built on models of costly consumer search. Examples include Abbott (1988), Borenstein and Rose (1994), Dahlby and West (1986), Pratt et al. (1979), and Stigler and Kindahl (1970). An absence of micro-level cost data is a limitation of many of the studies.

that have well-defined units of measure. [2] This shipments and quantity data allow us to construct plant-specific average prices, or unit values, for very disaggregated products in each census year. This paper focuses on the cross-section distribution of prices in a census year and the correlations between prices, markups, and plant size, for six well-defined homogeneous products. [3]

To study markups it is necessary to control for variation in material prices across establishments because raw materials can often account for more than 50 percent of plant production costs. The *Census of Manufactures* also collects data on the plant's expenditure on material inputs and the physical quantity of inputs purchased for detailed raw material categories from which we construct a plant-specific average price of materials for important inputs. The six products we study all have one or two well-defined material inputs that account for a significant fraction of total material expenditures in the plant.

There are many reasons to expect output price variation in micro data of this type including: data imperfections, product heterogeneity, and imperfect competition. Even if the output of different producers is perfectly homogeneous and output markets are perfectly competitive we could observe price dispersion because of measurement or reporting errors in the value or quantity of shipments data. [4] Measurement error in output can introduce a negative correlation between output price and plant size but prices should be uncorrelated with production costs and there should not be any serial correlation in the pricing patterns of individual plants.

We have attempted to minimize the impact of product heterogeneity by selecting outputs at the most disaggregated level for which data is collected. Despite this, there can still be differences in product quality across producers that we cannot observe. However, to the extent these differences are reflected in the plant's production costs, such as through the use of higher-quality, more expensive inputs, they can be controlled for with plant-level cost data. Thus, price variation that is not reflected in markup variation is consistent with unobserved quality differentials. Finally, if output markets are geographically segmented because of high transportation costs or spoilage problems then price dispersion can exist

[2] Four of the products studied in this paper, bread, gasoline, concrete, and tin cans, are seven-digit SIC categories while the remaining two, roasted coffee and corrugated boxes, are aggregates over several seven-digit categories. This is the most disaggregated level of product detail available with census data. Data is drawn from each of the last six censuses covering the years 1963, 1967, 1972, 1977, 1982 and 1987 for all products except tin cans, where data is not available after 1972.

[3] The results in this paper are part of a larger research project reported in Roberts and Supina (1995). There we analyze both cross-sectional and longitudinal patterns for twelve products.

[4] The fact that we only measure the average price over all the plants' sales in a year could also result in dispersion. If prices fluctuate over the course of the year and plants distribute their sales differently over time, price dispersion will be observed in the data even if all producers have identical prices at each moment.

across producers due to different cost conditions in the separate markets. This type of dispersion should be at least partly reduced when examining markups. [5]

If the product is truly homogeneous, with price dispersion generated solely by data errors and noise, there can still be systematic variation in markups if markets are not perfectly competitive. Cournot competition where producers have different cost functions, for example, will lead to markups that vary with producer size. In addition, if markets are geographically segmented and are characterized by different degrees of competition both price and markup variation will be observed. If there is costly consumer search then there can also be price dispersion even if products are homogeneous (see Stigler, 1961; Carlson and McAfee, 1983). Alternatively, if outputs are differentiated across producers, so that each plant faces its own unique demand curve, then prices will reflect both plant-level cost and demand conditions. Focusing on variation in plant-level markups, as opposed to just plant-level output prices, is then one way to attempt to isolate differences in demand elasticities among producers as determinants of output price.

While these competing explanations cannot be fully distinguished without a more completely-specified model of plant-level production and demand, the question we address is whether the observed dispersion is simply noise, generated by measurement errors, or whether it reflects underlying differences in the economic environment including production costs and output market competition. In this paper we focus on cross-sectional correlations between prices, markups, and plant size as one source of evidence on this issue. [6]

All six of the products we examine are characterized by cross-sectional price dispersion. A useful measure of dispersion, that is robust to measurement errors and outliers, is the difference between the 90th and 10th percentile of the distribution divided by the median. The average value of this measure is 0.653 for tin cans, 0.639 for bread, 0.539 for corrugated boxes, 0.420 for coffee, 0.353 for concrete, and 0.222 for gasoline, which indicates that all of the products have output prices that vary across plants. Examination of the dispersion measure in each of the census years reveals that the amount of dispersion for a given product is similar across years so the ranking of products from highest to lowest dispersion changes little over time.

There are several reasons to suspect that a plant's output price will be systematically related to its size. If larger plants serve larger, more competitive markets then their prices may be lower as a result of the increased competition. If larger plants have lower production costs, either because they are more efficient or

[5] The geographic variation may be particularly important for this group of products because four of them, cans, corrugated boxes, bread, and concrete are sold in fairly small geographic markets.

[6] Roberts and Supina (1995) exploit the panel nature of the data to look for persistence in the pricing patterns of plants over time. For all products examined we find substantial persistence in the location of plants in the price distributions for different years. The persistence is inconsistent with uncorrelated measurement errors being the primary source of price dispersion.

can exploit scale economies, these may be passed on to purchasers. If larger plants produce very homogeneous, standardized products while smaller plants manufacture specialty products and serve niche markets then costs and prices may vary with size.

We use a nonparametric kernel regression estimator to summarize the price-size relationship for a product. The conditional mean price, for a given plant log output level q, is estimated as

$$\hat{m}(q) = \frac{\Sigma_i K_h(q - q_i) P_i}{\Sigma_i K_h(q - q_i)}$$

where P_i is the price of output in plant i, K_h is the kernel, and the summation is taken over all observations in the data. In this case we use the Epanechnikov kernel which is defined as

$$K_h(q - q_i) = \frac{3}{4^h}\left(1 - \left(\frac{q - q_i}{h}\right)^2\right) I(|q - q_i| \leq h)$$

where h is the bandwidth and I is an indicator function that takes the value one if q and q_i are within h of each other and zero otherwise.

To facilitate comparisons across products, each plant's log output is normalized by the log output of the smallest plant in the sample. We remove price level changes over time and pool observations across census years by expressing each plant's price in logs relative to the mean price of the product in the census year. Specifically, the price for plant i in year t is given as $\ln P_{it} - \ln P_t$ where P_t is the mean price over all plants in year t. As a result, the nonparametric regressions summarize the average proportional deviation of plant prices, for plants of a given size, from the mean price of the product in the same year.

The kernel price regressions are graphed as the solid line in Fig. 1. (The two dashed lines are the regression functions for the plant's marginal cost and markup and will be discussed later.) For five of the six products the price of output declines as plant size increases. The price decline is most substantial for corrugated boxes, where the smallest plants have prices approximately 20 percent above the mean price in each year and the largest plants have prices approximately 10 percent below the mean. The price decline is monotonic across the size distribution. Bread and concrete also have substantial monotonic declines in price as plant size increases. The price declines for roasted coffee and tin cans are more modest but still indicate approximately a 10 percentage point difference between prices of the smallest and largest plants. The one product that does not show any relationship between output price and plant size is gasoline.

We check if the price differences are statistically significant by conducting parametric tests of the equality of mean prices across quartiles of the plant size distribution. We regress the log of the plant's output price relative to the yearly

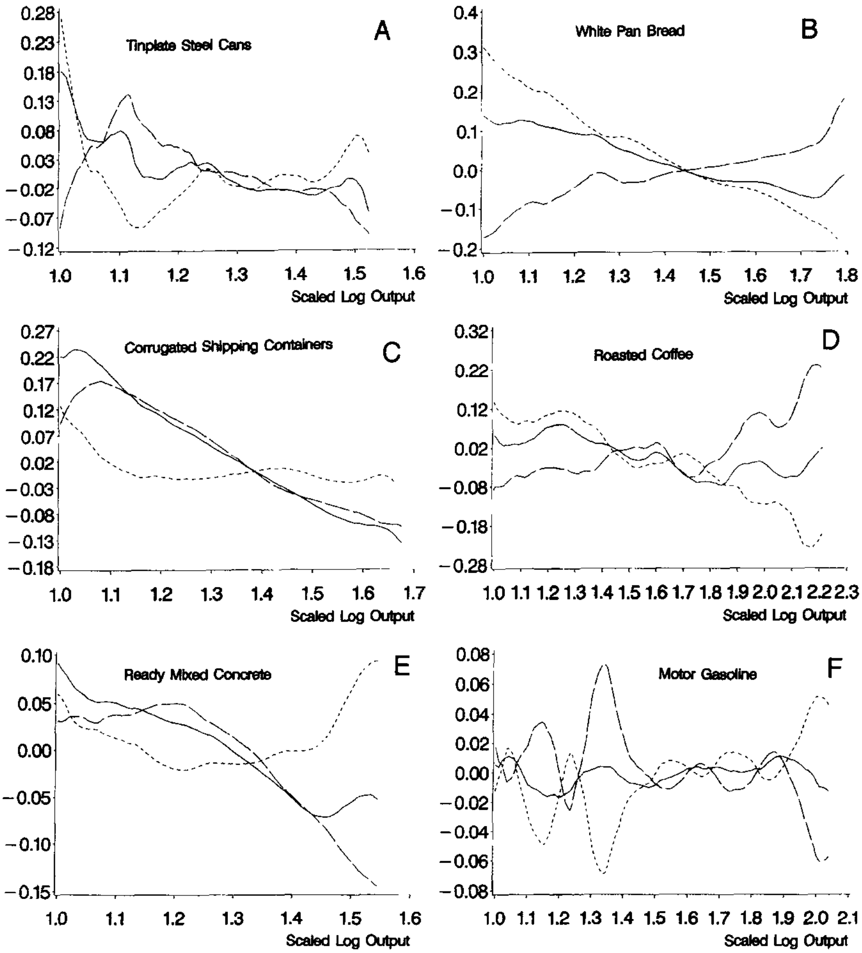

Fig. 1. Kernel price regressions

mean on dummy variables for the plant's size quartile. [7] Results and tests for equality of means are reported in Table 1. In these regressions β_1 represents the smallest size quartile and the other coefficients represent deviations from this for the three larger quartiles. The estimates of β_1 show that, with the exception of

[7] A negative correlation between price and plant size can also result from measurement error in the plant's physical output because the price is constructed as the ratio of revenue to physical output. Errors in output are transmitted negatively to output price. The quartile regressions will be more robust to this type of measurement error bias. Roberts and Supina (1995) provide additional evidence derived from the longitudinal component of the data that indicate measurement error in output is not the source of the negative correlation between plant size and output price.

Table 1
Output price differences by size quartile(standard errors in parentheses)

Product	β_1	β_2	β_3	β_4	F stat. $\beta_2 = \beta_3 = \beta_4 = 0$	F stat. $\beta_2 = \beta_3 = \beta_4$	F stat $\beta_3 = \beta_4$	Obs.	R^2
Tinplate steel cans	0.037	−0.37	−0.61 **	−0.49	1.32	0.40	0.24	712	0.01
	(0.025)	(0.032)	(0.029)	(0.030)					
White pan bread	0.091 **	−0.88 **	−0.136 **	−0.139 **	35.21 **	11.90 **	0.06	2807	0.05
	(0.011)	(0.014)	(0.013)	(0.013)					
Corrugated shipping containers	0.136 **	−0.119 **	−0.185 **	−0.240 **	242.09 **	138.51 **	83.28 **	4571	0.18
	(0.009)	(0.011)	(0.010)	(0.010)					
Roasted coffee	0.047 **	−0.021 **	−0.079 **	−0.089 **	8.28 **	8.51 **	0.31	762	0.04
	(0.013)	(0.018)	(0.019)	(0.019)					
Ready-mixed concrete	0.046 **	−0.028 **	−0.059 **	−0.096 **	122.05 **	119.92 **	71.50 **	11360	0.04
	(0.003)	(0.004)	(0.004)	(0.005)					
Motor gasoline	−0.004	0.003	0.008	0.005	0.23	0.21	0.16	964	0.001
	(0.006)	(0.009)	(0.009)	(0.009)					

** :: Significant at the $\alpha = 0.05$ level.

gasoline, the smallest producers have prices above the mean and the magnitude of the coefficient corresponds closely with that observed in the nonparametric regression figures. The significant negative estimates for the other coefficients indicate a statistically significant decline in the mean price across the size distribution.

The hypothesis that the mean price is constant across the four quartiles ($\beta_2 = \beta_3 = \beta_4 = 0$) is rejected, based on the F-statistic reported in column 5, for all products except tin cans and gasoline. (Two of the individual coefficients for tin cans are statistically significant, however.) So too is the hypothesis that only the plants in the smallest size quartile have average prices that differ systematically from the other plants ($\beta_2 = \beta_3 = \beta_4$). Finally, the hypothesis that plants in the largest two quartiles have equal prices ($\beta_3 = \beta_4$), is rejected for two of the products, boxes and concrete. The results indicate that these two products have systematic price declines which continue across the whole size distribution, and this is also evident in the kernel regressions in Fig. 1. For two of the products, bread and coffee, we do not reject that plants in the largest two quartiles have equal mean prices which indicates that the significant price declines are concentrated among the smaller plants.

Overall, the pattern that emerges from Fig. 1 and Table 1 is that, in the cross-section, output prices decline with plant size for all products except the one, gasoline, for which there is very little overall dispersion. The observed cross-sectional price variation is not simply random noise that is uncorrelated with the characteristics of the producer. [8]

3. Marginal cost, markups, and plant size

In order to study the cross-sectional pattern of plant-level markups we construct plant-specific estimates of marginal cost. Details of the methodology are provided in Supina (1994) and only a few important issues are mentioned here. First, virtually all plants produce more than one output and ignoring these other outputs would bias scale parameters and marginal cost estimates. To account for this we aggregate the shipments of all other products manufactured in the plant into a single secondary output, deflate this with an industry-level price index, and

[8] Further evidence that the price variation is not random can be seen by examining the correlation of prices across different census years. If the distribution of prices reflects underlying differences in cost, product quality, or extent of market competition that change slowly over time then plant's should remain in approximately the same part of the price distribution across years. The rank correlation of plant prices across adjoining census years (a five-year interval) is reasonably high for all the products studied suggesting an important role for permanent cost or competition differences. The products and correlations are: tin cans (0.55), bread (0.43), corrugated boxes (0.46), concrete (0.45), coffee (0.36) and gasoline (0.25). Again, gasoline shows the least evidence of systematic price dispersion.

include it as a second output in multiproduct cost models. Second, data for the book value of capital stocks is available by plant in most years but no information on plant service prices or expenditures on capital input is collected. Because of this, cost is defined as the plant's expenditure on materials, labor, and energy inputs. When interpreting patterns of cost and markup variation it is important to recognize that we may systematically underestimate marginal cost and, if large plants are more capital intensive, the bias will increase with plant size. Finally, we utilize flexible forms for the cost function (translog) so that estimates of marginal cost vary across plants with difference in labor, energy, and material prices, levels of the two outputs, year, and a single-unit\multi-unit ownership dummy that controls for possible differences in capital prices, or the way that central office expenditures are allocated.

The cross-sectional variation in marginal cost and its relationship to plant size is summarized with a kernel regression and displayed as a short dashed line in Fig. 1. It represents the percentage deviation of marginal cost from the mean level in the same census year. The change in marginal cost across the size distribution reflects the combined effect of scale economies and differences in factor prices and output mix. For all products we estimate slight increasing returns to scale which contributes to a decline in estimated marginal cost as plant size increases. [9]

The patterns summarized in Fig. 1 indicate that for two of the products, coffee and bread, marginal costs decline systematically with plant size across the whole size distribution. Two other products, corrugated boxes and tin cans, have cost declines as the plants increase in size until they are approximately 10 percent larger than the smallest plant (scaled log output equals 1.1), but no further declines after that. The final two products, concrete and gasoline, show no systematic pattern of cost variation with plant size.

We construct the plant-level markup as the logarithm of the ratio of the plant's output price and marginal cost: $\ln(P_i/MC_i)$. If each plant i produces a differentiated product and faces its own downward sloping demand curve with elasticity η_i then, using the first-order condition for profit maximization, the markup for plant i can be expressed as $\ln(P_i/MC_i) = -\ln(1 - 1/\eta_i) + \epsilon_i$, where ϵ_i represents all random sources of price or cost variation. As the number of alternative producers or the degree of substitutability among producers' output increases, the higher is η_i and the lower is plant i's markup. If larger plants have lower demand elasticities because there are fewer alternative products available to purchasers, then markups should rise with plant size.

In the case where all plants produce a homogeneous product, the markup can be written as $\ln(P_i/MC_i) = -\ln(1 - (\lambda s_i)/\eta) + \epsilon_i$, where s_i is the plant's market share, λ is the index of competitiveness of the market in which it operates (see

[9] The scale elasticity estimates for each product, evaluated at the means of the data, are: bread (1.18), coffee (1.04), corrugated boxes (1.07), gasoline (1.02), tin cans (1.02), and concrete (1.13).

Bresnahan, 1989), and η is the market demand elasticity. Within the market, plants with larger market shares will have larger markups. [10] In addition, in this case anything that decreases η or increases λ will increase the markups of all plants in that market. This could contribute to a negative markup-size relationship if markets were geographically segmented and larger plants operated in larger, more competitive markets. [11]

Variation in the markup with plant size is summarized with kernel regressions that are represented by the long dashed line in Fig. 1. The markup is expressed as the log deviation from the yearly mean over all producers and thus a negative value in the graph indicates that the markup is below the year mean, not that it is negative. [12] We also estimate regressions of the markup on dummy variables for the quartiles of the size distribution and these are reported in Table 2 and interpreted in the same way as the estimates in Table 1.

Based on both sources of evidence, we find for gasoline that there is very little variation in the markup and it is not systematically related to plant size. This is not surprising when combined with the fact that there was no systematic pattern in the output prices and we estimated constant returns to scale in production. Of the six products examined here, gasoline is the one that appears closest to a random, noise-driven price distribution.

For three products, cans, corrugated boxes, and concrete, the markup declines significantly with increases in plant size across the whole size distribution. This decline is mainly driven by declining prices combined with fairly stable marginal cost. All of these products are sold in fairly small geographic markets and the price and markup patterns are both consistent with the argument that larger plants are located in larger, more competitive markets. The final two products, bread and coffee, both have markups that increase significantly with plant size, although for coffee the increase is only significant for the largest quartile of producers. The increasing markups result because marginal cost declines more rapidly than output price. While efficiency differences among large and small plants can explain the decline in marginal cost, and large plants operating in more competitive markets

[10] If we adopt the homogeneous product framework to explain markup variation then we must rely solely on random measurement errors and other sources of noise in the data collection process to explain the presence of output price dispersion. The differentiated product framework could generate price as well as markup variation.

[11] Dunne and Roberts (1992) provide evidence that there is no systematic decline in market price with increases in the number of producers among small geographic markets for the U.S. bread industry. The vast majority of their contain 10 or more bread producers suggesting little variation in λ across markets in their data.

[12] The graphs in Fig. 1 do not allow comparisons of the levels of price, marginal cost, and the markup since each is normalized by its own yearly mean. The average value of the ratio of price to marginal cost is 1.85 in bread, 1.4 in concrete, 1.33 in cans, 1.25 in coffee, 1.22 in boxes and 1.05 in gasoline. The level of this ratio is affected by the importance of capital in the production process since capital expenditures are omitted from the marginal cost estimate.

Table 2
ln(price/marginal cost) differences by size quartile (standard errors in parentheses)

Product	β_1	β_2	β_3	β_4	F stat $\beta_2=\beta_3=\beta_4=0$	F stat. $\beta_2=\beta_3=\beta_4$	F stat. $\beta_3=\beta_4$	Obs.	R^2
Tinplate steel cans	0.083 **	−0.065	−0.108 **	−0.159 **	8.84 **	7.16 **	4.30 **	669	0.05
	(0.029)	(0.036)	(0.035)	(0.033)					
White pan bread	−0.057 **	−0.054 **	0.069 **	0.108 **	10.69 **	6.84 **	6.55 **	2637	0.02
	(0.012)	(0.016)	(0.016)	(0.018)					
Corrugated shipping containers	0.112 **	−0.096 **	−0.164 **	−0.189 **	149.85 **	66.99 **	15.55 **	4393	0.12
	(0.009)	(0.012)	(0.010)	(0.010)					
Roasted coffee	−0.050	0.045	0.041	0.115 **	3.73 **	4.56 **	7.65 **	637	0.02
	(0.023)	(0.028)	(0.028)	(0.030)					
Ready-mixed concrete	0.027 **	0.013 **	−0.022	−0.099 **	44.66 **	78.23 **	77.83 **	6045	0.03
	(0.010)	(0.012)	(0.012)	(0.012)					
Motor gasoline	0.019	−0.023	−0.029	−0.022	0.72	0.15	0.24	918	0.00
	(0.015)	(0.019)	(0.018)	(0.019)					

** Significant at the $\alpha = 0.05$ level.

could explain the decline in price, together they do not appear likely to explain the rising markup. In the case of coffee, more inelastic demand for the output of the larger plants is possible because these plants tend to be operated by the large national firms that rely more heavily on advertising to differentiate their products. An alternative, data-driven explanation is that large coffee and bread plants are significantly more capital intensive than their smaller rivals and the increase in the markup we observe results from underestimating marginal cost for large plants.

4. Summary and conclusions

In this paper we exploit data on output prices at the plant-level to study the dispersion of prices, their correlation with producer size, and their correlation with production costs for six homogeneous manufactured products: white pan bread, coffee, tin cans, corrugated boxes, ready-mix concrete, and gasoline. The data reveal clear patterns of price dispersion among producers with the amount of dispersion varying across products. Nonparametric regressions reveal that, for all products except gasoline, output prices decline with increases in plant size.

Cost function models are estimated and used to construct plant-specific estimates of marginal cost and markups. The change in the price–cost ratio as the plant size increases depends on the relative decline in output price and marginal cost. Three of the products that are sold in geographically-segmented markets, cans, concrete, and boxes, are characterized by declining prices and declining markups as plant size increases. The decline in the markup is particularly strong given that the absence of capital expenditure data suggests we are most likely to underestimate marginal cost, and thus overestimate the markup, for large plants.

Two products, coffee and bread, have declining output prices and rapidly declining marginal costs that combine to generate a positive correlation between markups and plant size. For these products cost differences appear to be an important determinant of output price dispersion. The final product, gasoline, has the smallest degree of price dispersion, no systematic relationship between price and plant size, little cost variation among producers, and no relationship between size and the markup. Unlike the other five products, the observed heterogeneity among gasoline plants does not appear to be economically meaningful and is probably best described by a process of noisy data collection.

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