PRICE DISPERSION IN U.S. MANUFACTURING: IMPLICATIONS FOR THE AGGREGATION OF PRODUCTS AND FIRMS

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CES 92-3 March 1992

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Abstract

This paper addresses the question of whether products in the U.S. Manufacturing sector sell at a single (common) price, or whether prices vary across producers. Price dispersion is interesting for at least two reasons. First, if output prices vary across producers, standard methods of using industry price deflators lead to errors in measuring real output at the industry, firm, and establishment level which may bias estimates of the production function and productivity growth. Second, price dispersion suggests product heterogeneity which, if consumers do not have identical preferences, could lead to market segmentation and price in excess of marginal cost, thus making the current (competitive) characterization of the Manufacturing sector inappropriate and invalidating many empirical studies. In the course of examining these issues, the paper develops a robust measure of price dispersion as well as new quantitative methods for testing whether observed price differences are the result of differences in product quality. Our results indicate that price dispersion is widespread throughout manufacturing and that for at least one industry, Hydraulic Cement, it is not the result of differences in product quality.

Keywords: Price indices, real output, productivity, product quality

*The author would like to thank Zvi Griliches, Richard Caves, Tim Dunne, Dennis Fixler, Michael Frierman, Jerry Hausman, Robert McGuckin, Sang Nguyen, Stuart Theil and Peter Zadrozny for their many helpful comments on earlier drafts of this material. Financial support from the Rutgers University Research Resources Committee is gratefully acknowledged.

I. INTRODUCTION

This paper originated from the casual observation that in many instances consumers can purchase identical (or nearly identical) products at a wide range of prices from different sellers. Clearly, such an observation rejects the economists' notion of perfectly competitive markets and question the validity of the law of one price. This observation is not original, for example, Stigler (1961) used similar observations to introduce his theory of incomplete information. This paper, however, takes a different course and asks not what imperfections might explain this phenomenon but rather whether price dispersion is widespread, and how it affects the standard analysis of firm and industry data. Specifically, Section II begins by asking why the issue of price dispersion is important for the analysis of productivity and the theory of aggregation. It shows that if prices vary across producers, the usual method of using industry price deflators leads to errors in measuring real output at the firm or establishment level.[1] These errors in turn lead to biased parameter estimates of the production function and productivity growth equation as shown in Abbott (1991), and could invalidate many of the empirical studies which have populated the productivity and industrial organization literature.[2]

Section III examines evidence on the existence and extent of price dispersion. To date, several papers have appeared in the literature on this subject. Theoretical explanations for the existence of price dispersion in specific markets are provided by

Burdett and Judd (1983), Carlton (1979, 1986), Perloff and Salof (1986), Salop and Stiglitz (1977), Reiganum (1979) and Phlips (1988). Much of this literature is based on the incomplete information hypothesis proposed by Stigler, although one could view this as a special case of the product differentiation and monopolistic competition models discussed by Salop and Stiglitz (1977), Stiglitz (1984) and others. Empirical evidence supporting price dispersion has been reported by Dahlby and West (1986), Isard (1977), Pratt et al. (1979), and Stigler and Kindahl (1970).[3] These studies, however, have had limited impact on the productivity and industrial organization literature because they focus on relatively few products and they typically failed to connect the pricing decision to the production decisions. Pratt et al., for example, examined several products at retailers in the Boston area, while Stigler and Kindahl examined buyer-seller transactions for several industrial goods but discounted the observed dispersion as the result of transaction heterogeneity. Because of these limitations, one cannot generalize these studies to determine the importance of price dispersion across industries, or the level of price variation within specific industries. In examining a new data set, this paper measures the level of price dispersion for over 2400 7-digit (SIC) products in this vital sector of our economy.[4] Our results, using a newly developed robust measure of price dispersion, indicate that there are substantial differences in prices across producers, and that this phenomenon occurs in almost every industry.

Section IV introduces the subject of product quality (a common explanation for observed price dispersion). In this section, we develop a methodology to determine whether the existing price dispersion is the result of differences in product quality. Using data from the Hydraulic Cement industry, we show that the observed price dispersion cannot be explained by differences in product quality, suggesting that price dispersion could create problems for the analysis of this industry. Although the results are not directly applicable to other industries, they do raise questions about the wisdom of ignoring the effects of price dispersion in light of the findings in the previous section.

The final section discusses additional areas of research needed to more fully test the unique price theory, and to determine the impact of price dispersion on the existing productivity, profitability, and market structure studies.

II. PRICE DISPERSION, PRODUCTIVITY, AND THE THEORY OF AGGREGATION

The existence of price dispersion across sellers poses several problems for the empirical analysis of microeconomic and industrial behavior. This section is divided into two parts. In the first part, we examine the problems price dispersion introduces in the context of an industry producing a single homogeneous product. In the second part, we re-examine price dispersion in the context of multi-product firms.

Single Product Industries

Support that all of the firms in an industry produce a single homogeneous product, Q, but that each firm is able to set its product at a different price. These price differences could be the result of long term contracts, price discrimination, incomplete information, or spatial competition without affecting our analysis. In empirical work, measures of real output are generally constructed using deflated sales because sales (rather than quantity) data is more readily available (for example, COMPUSTAT and the Bureau of a the Census collect primarily sales data.) Letting Q_{it} and P_{it} represent the output and price for firm i in period t, this measure can be written as

$$(1)\quad \mathcal{Q}_{it} = S_{it}/D_t = Q_{it} * (P_{it}/D_t),$$

where S_{it} is the sales for firm i in period t and D_t is the "industry" price deflator for period t. As shown in equation (1), using the deflated sales measure introduces an error because the term in parentheses is not (generally) equal to 1. In most instances, researchers examine the log of sales (representing the natural log with lower case letters) so that this equation becomes

$$(2)\quad \mathcal{q}_{it} = q_{it} + (p_{it} - d_t),$$

and the measured output is equal to the actual output plus an additive error. In regression analysis, using a variable measured with error as a dependent variable does not introduce biases unless that error is also correlated with variable included on the right hand side of the equation. As shown in Abbott (1991), firm specific prices will frequently be correlated with the variable factors of production and variable factor costs; thus the necessary assumption of independence of the measurement error can often be rejected.[5] As a result, studies using firm or establishment data, deflated with an industry price deflator, will suffer from a correlated errors problem if the prices differ across producers in the industry. Since this micro-data/macro-deflator approach has become the norm for empirical studies of firm and industry behavior, it is important to determine if price dispersion across sellers is a widespread phenomenon.

Turning to the question of aggregation, we find that most empirical work at the industry level use a measure of deflated sales as real output. That is,

(3) $\mathit{Q}_t = G_i\ S_{it} / D_t = G_i\ Q_{it} * (P_{it} / D_t)$,

Where Q_t is measured industry output and the other variables are defined as above. To determine the effect of using an industry deflator, it becomes necessary to understand how the price deflator was constructed. If the price deflator is measured as a quantity weighted average of all individual firm prices, i.e.,

(4) $D_t = G_i\ P_{it} * (Q_{it} / Q_t)$,

where Q_t is the actual industry aggregate output ($Q_t = G_i\ Q_{it}$), then it is relatively straight forward to show that there is no bias and

(5) $\mathit{Q}_t = Q_t$,

Unfortunately, in most instances industry price deflators are not constructed in this manner. For example, the Bureau of Labor Statistics constructs the Producer Price Index as an revenue weighted average of the relative prices of selected products from one period to the next. Ignoring the sampling aspects of the problem, this price index can be written as, [6]

$$(6)\ (D_t/D_{t-1}) = G_i\ (P_{it}/P_{it-1}) * (S_{it},/S_t,),$$

or in terms of D_t as

$$(7)\ D_t = G_i\ P_{it} * \{(S_{it},/S_t,) * (D_{t-1}/P_{it-1})\}$$

where the second term represents the revenue weights (typically determined at an earlier point in time) and the third term captures the fact that the index is constructed in the form of price relatives rather than price levels.[7]

The key questions which we will now address are: (1) Under what conditions does the constructed price index provide the correct measure of real output? and (2) Under alternative conditions, is there a consistent bias introduced because of the incorrect weights? In addressing these questions, it is convenient to look at the ratio of the measured real output (Q_t) to actual aggregate output (Q_t). As shown in the appendix, letting $*_{it}$ represent the relative prices for firm i, that is (P_{it}/P_{it-1}), and N_{it}, represent the revenue share weights in the base year, i.e., ($S_{it},/S_t,$), this ratio can be expressed as

$$(8)\quad Q_t/Q_t = (D_{t-1}/D_{t-1}) * (D_t/D_{t-1}) / (N\ \mathrm{Cov}\{*_{it},N_{it},) + E_i *_{it}/N)$$

where the first term (the ratio of the true price deflator, equation (4), to the measured price deflator, equation (7)) is a constant representing the normalization of the price index in period t-1; the second term represents the actual industry price growth rate (based on the true price deflator, equation (4)); and the third term incorporates the average firm price growth rate and the covariance between the firm price growth and the revenue weights used to construct the price index. Thus, deflated sales will provide the correct measure of real output over time (up to an arbitrary constant) only if the second and third terms exactly cancel.

In examining this condition further, it is useful to start off by assuming that all firm prices grow proportionately, ie $*_{it} = *_t$ for all i. In this case,
the covariance term disappears, and equation (8) reduces to

$$(9) \quad \mathit{Q}_t/Q_t = (D_{t-1}/\mathit{D}_{t-1}) * (D_t/D_{t-1}) *_t .$$

Thus, we are left asking under what circumstances the true price deflator D_t, defined in equation (4), grows at the same rate as each of the firm's price. A sufficient condition is that there is no change in quantity shares. In this case, revenue shares also remains constant, and deflated sales provides the correct measure of output. But are these assumptions a reasonable representation of the real world? In the case of incomplete information and repeated purchases, if all prices grew at the same rate (but each firm had a different price), one would anticipate consumers gradually drifting towards the sellers with the lowest price as they gathered more information about the market, as discussed in Phlips (1988).[8] Thus, under the condition that all prices grew at the same rate, one would expect to find that the revenue weighted price index, given in equation (7), would tend to overstate the aggregate prices increase, and therefore understate the real output growth of the industry.

If we relax the assumption of constant price growth, we immediately run into a question of how the current price growth rates are correlated with the original revenue shares. If we make an assumption of zero correlation, our problem reduces to an expression similar to equation (9) except that $*_t$ is replaced by the equally weighted average firm price growth rate. Thus, the question of bias turns on the ratio of the aggregate price growth rate to the mean price growth, and without additional assumptions it is unclear whether the revenue weighted index over or under states the price growth. Further relaxing the assumption of zero correlation makes it clear that there is little hope of establishing any conclusive answer of whether the revenue weighted index over or understates the true price/quantity growth in the context of firm specific prices - although it is clearly unlikely that the price index would provide the correct measure. Thus, in general, it is not clear whether the period to period changes in industry sales deflated by the commonly available indices are due to (1) changes in firm prices, (2) changes in firm output, or (3) changes in the distribution of sales across the different prices available on the market.

Multi-Product Industries

While the single product example is useful for expository purposes, it is hardly the norm. In most industries, there are a large number of products (or goods) manufactured, with each firm producing only a subset of the goods available in the market. Despite this characterization, it has become standard practice in empirical work to make the assumption that the output across these different products can be aggregated and treated as if it were a single product. Typically, such aggregation is done in terms of sales rather than quantities, and thus researchers implicitly use relative prices as the "weights" for aggregation, that is

$$(10)\quad Q_{it} = S_{it}/D_t = \Sigma_j\, Q_{ijt} * P_{ijt}/D_t,$$

where j denotes the individual products produced by firm i in period t. Thus, in addition to the problems introduced by using a common industry price deflator D_t across all firms, discussed above, we must also examine the implications of using the relative prices across goods as weights for aggregation into a "real" output index.

To begin our discussion of the multi-product context, it is not obvious what one means by the concept of real output for the firm producing several goods (i.e., how does one aggregate apples and oranges?) Fisher and Shell (1972), in their classic text The

Economic Theory of Price Indices, offer some guidance in this area by looking at the production possibility frontier (PPF). Given a set of endowments $\mathbf{V} = (v_l...v_m)$, outputs $\mathbf{X} = (x_l...x_r)$ (vectors denoted with bold), and technology defined by

(11) $F(\mathbf{X}, \mathbf{V}) = 0$,

one can derive the PPF associated with any vector of inputs. They argue that any two points (vectors of outputs), for example $\mathbf{X_a}$ and $\mathbf{X_b}$ in figure 1, along the same PPF must have the same level of real output by virtue of the fact that both points efficiently used all of the available inputs.[9] A linear approximation to trade off between goods 1 and 2 in going from $\mathbf{X_a}$ to $\mathbf{X_b}$ is provided by the secant line passing through these two points. Using the mean value theorem, the slope of the secant line is equal to the slope at some point between $\mathbf{X_a}$ and $\mathbf{X_b}$ and in the limit as $\mathbf{X_a}$ approaches $\mathbf{X_b}$ is equal to the tangent line at that point. Thus, in n-space, the hyperplane tangent to $F(\mathbf{X,V})$ at any particular point provides a local approximation of the tradeoffs available between each of the outputs given the existing technology, i.e., the marginal rate of product transformation. Under conditions of competitive equilibrium, the slope of this hyperplane is also given by the relative prices of each of the goods. Thus, under these conditions, the relative prices provide appropriate weights for determining the level of a real output index in the neighborhood of the equilibrium point.[10]

In figure 2, letting the first good serve as numeraire with price $p_{1a} = 1$, we compare the situation in which $\mathbf{X_a}$ is the optimal output vector under relative price vector $\mathbf{P_a}$, and $\mathbf{X_b}$ is the optimal output under relative price $\mathbf{P_b}$. Under the above definition of real output, these two points have the same level of real output because they lie on the same PPF and thus differences in nominal output are merely a monetary phenomenon. That is, let

$$(12)\quad Q_a = Y_a = \mathbf{P_a}\ \mathbf{X_a}$$

$$Q_b = Y_b \ * D_b = (\mathbf{P_b X_b}) * D_b$$

but because $\mathbf{X_a}$ and $\mathbf{X_b}$ lie on the same PPF, we define real output to be the same and,

$$Q_a = Q_b$$

$$(\mathbf{P_a}\ \mathbf{X_a}) = (\mathbf{P_b}\ \mathbf{X_b}) * D_b$$

or $\quad D_b = (\mathbf{P_a}\ \mathbf{X_a}) / (\mathbf{P_b}\ \mathbf{X_b}) = Y_a/Y_b.$

Thus, under Fisher and Shell's definition of real output, having knowledge that two points are on the same production possibility frontier allows us to explicitly derive the true price index (D_b). Letting period a be the base period, this index can be equivalently written as either the product of a Laspeyres Quantity Index and a Paasche Price Index; or the product of a Laspeyres Price Index and a Paasche Quantity Index, as shown by

$$D_b = (\mathbf{P_a}\ \mathbf{X_a} / \mathbf{P_a}\ \mathbf{X_b}) * (\mathbf{P_a}\ \mathbf{X_b} / \mathbf{P_b}\ \mathbf{X_b})$$

$$= (\mathbf{P_a}\ \mathbf{X_a} / \mathbf{P_b}\ \mathbf{X_a}) * (\mathbf{P_b}\ \mathbf{X_a} / \mathbf{P_b}\ \mathbf{X_b}).$$

Thus, neither of the standard Paasche or Laspeyres prices indices is able to adequately measure the change in prices by itself. Unfortunately, it must be stressed that this derivation applies only to the special case in which both points are known to lie on the same PPF.

In general, we are interested in comparing situations in which the PPF may have changed and the question is whether we can use index numbers to measure the real output in this context. Figure 3 illustrates a situation in which firm b's PPF lies entirely outside the PPF of firm a. A sufficient condition for this to occur is for $\mathbf{V_b > V_a}$; that is, firm b has at least as much of each input as firm a and strictly more for at least one input and that the marginal productivity of each input for each product is strictly positive. If, in addition, both firms face the same price vector and successfully maximize profits, then it is clear from figure 3 that if $Y_b > Y_a$ then ambiguously the real output of firm b is greater than firm a.[11]

If, however, firms face different relative price vectors, as may be the case if individual product prices vary across firms, then it is clear that total sales no longer provides a reliable measure of real output - see figure 4. In this example, firm a faces prices $\mathbf{P_a}$ and chooses to produce $\mathbf{X_a}$ while firm b faces price $\mathbf{P_b}$ and will produce at point $\mathbf{X_b}$. This problem is identical to the more general problem of developing price and quantity indices for the economy as a whole. Fisher and Shall (1972) examine this problem and show that there exist two possible measures of real output index:

(13) $Y_b/Y_a = (Y_b/Y_{b},) * (Y_b/Y_a) = (Y_b/Y_{a},) * (Y_a/Y_a)$

where $\mathbf{X}_{a'}$ represents what firm a would have produced had they faced prices $\mathbf{P}_b$, and $\mathbf{X}_{b'}$ represents what firm b would have produced had they faced prices $\mathbf{P}_a$. In the first decomposition, the term $(Y_b/Y_{b'})$ represents the effects of the changes in prices in a manner analogous to figure 2, and the second term $(Y_{b'}/Y_a)$ represents the real output index. In the second decomposition, the terms are reversed; i.e. $(Y_b/Y_{a'})$ represents the real output index and $(Y_{a'}/Y_a)$ represents the price effects. These two indexes yield the same results only in the case of homothetic production technologies. Thus, in order to construct the correct real output index, one must know the production technology and construct output vectors under hypothetical price vectors.

Under more general circumstances, where such strict input dominance can not be established, an interesting paradox arises. In figure 5 we see that the PPF for firm a and firm b intersect. Under the Fisher and Shell definition of real output (which we have been using throughout this discussion) we see that points $\mathbf{X}_a$ and $\mathbf{X}_c$ lie on firm a's PPF and thus must have the same level of real output; with $\mathbf{X}_b$ and $\mathbf{X}_c$ lie on the same PPF for firm b, and hence must have the same real output. Using the transitivity property, we conclude that $\mathbf{X}_a$ and $\mathbf{X}_b$ therefore must have the same level of real output, even though $\mathbf{X}_a$ provides strictly more of each good than $\mathbf{X}_b$. Fisher and Shell carefully avoid this situation by examining only a family of PPFs determined by

(14) $F(\mathbf{X},\mu\mathbf{V}) = 0$, such that $\mu > 0$

where changes in μ denote proportional increases/decreases in all inputs.[12] We can resolve this dilemma by evaluating the two points using only one of the PPF's in a manner similar to this. Noting that firm a could have produced $\mathbf{X}_b$ given its resources (hence $\mu_a < 1$), while firm b would require additional resources to produce $\mathbf{X}_a$ ($\mu_b > 1$) using its mix of inputs, we can conclude that $\mathbf{X}_a$ is a higher level of real output than $\mathbf{X}_b$. It is, however, unlikely that these two measures (μ_a and $1/\mu_b$) will yield compatible indices.[13] Moreover, if we try to extend this to more than two firms, it becomes clear that the index and even the rankings of the firms, may depend on our choice of "base" firm. For example, if instead of $\mathbf{X}_b$ we consider the point $\mathbf{X}_b$, (in figure 5), no natural ordering exists. That is, firm a would require more resources to produce $\mathbf{X}_b$, while firm b still requires more resources to produce $\mathbf{X}_a$. Thus, regardless of which firm we used as our "base" we would conclude that the other has less "real output." One might argue that this is not economical for two firms in the same industry to have such different mixes of the inputs as to result in PPF's which intersect in a manner similar to figure 5. While there may be some validity to this is a world where all inputs instantaneously adjust to current market conditions (and firms face competitive input prices) if some inputs are fixed in the short run, it is possible that two firms could find themselves in this situation given different histories. Moreover, the latter situation may be more realistic for the kinds of data we examine when looking at the Manufacturing

Sector of our economy.[14]

If pure technological reasons do not suffice, what is the justification for looking at total sales as a measure of real output across? The answer must be sought on the basis of consumer utility. In this regard, relative prices provides a method of measuring how "society" values the output of the firm, that is, using relative price weights provides an answer to the question, "In terms of what society wants today, which firm is able to provide more goods and services?" Thus, our total sales measure of real output must be justified on the interaction between production technology and consumer utility. The problem is of course, that now, if consumer tastes change (thereby changing relative prices across the goods) we are in a situation where the movement from $\mathbf{X}_a$ to $\mathbf{X}_b$ in figure 2 represents a change in real output (which, under our pure technological considerations we had called a monetary phenomenon) and the decomposition presented in equation (13) is no longer meaningful. Moreover, in the situation in which the PPF's cross, as depicted in figure 5, it is clear that even if both firms face the same relative prices, using total sales one could conclude that firm a has either higher, the same, or lower, real output depending upon the slope of the price vector.

In practice, the approach used in empirical work usually corresponds to an assumption that the prices of all goods more proportionately. For example, the Bureau of Labor Statistics defines the Producer Price Index as a weighted average of the price growth rates across a sample of firm-goods. Rewriting equation (6) to incorporate multiple goods indexed with j and again ignoring the sampling problem, we find that

(6') $(D_t/D_{t-1}) = E_i E_j \, (P_{ijt}/P_{ijt-1}) * (S_{ijt},/S_{jt},)$.

One rationale for this assumption is that the goods are perfect substitutes - that is, the production possibility frontier is a straight line and individual goods are, in the language of Tirole (1988), vertically differentiated, as in 5 and 10 lb bags of sugar. In such a case, it is clear that in a competitive market the relative price of the two products must be fixed and equal to the marginal rate of product transformation, else manufacturers would switch to producing only one type of product. However, in the more general case in which there is both horizontal and vertical product differentiation, such as assumption of proportional price increases may not be warranted. In this case, a price index which is based on an assumption or proportional price movements would clearly yield an incorrect measures of real output and the more general output index must be used.

Thus, in the context of a multi-product industry, price dispersion across firms introduces severe complications to the construction of price indices and for the aggregation of products and firms. And in general, total sales no longer provides a reliable measure of total output without additional assumptions about the slope of the relative price vector and the production technology.

III. EMPIRICAL PRICE DISPERSION

The Bureau of the Census collects data on value and quantity of shipments (FOB - plant gate) at the 7-digit product level as part of the Census of Manufactures. Implicit average prices (unit values) were constructed for each establishment-product in the 1982 Census of Manufactures. These prices provide the basis for this analysis.

Starting with 804,757 observations on annual establishment-product shipments, 144,377 observations were found to have usable value and quantity data.[15] For a general analysis of price dispersion across plants, the sample was further restricted to exclude certain types of broadly defined products: the "Not Specified by Kind" and "Not Elsewhere Classified" products.[16] And finally, the sample was restricted to only those products with 10 or more establishments having usable data.[17]

Imposing these additional restrictions limited the sample to a total of 112,630 establishment-product observations on 2,430 different products. For each product, two statistics were initially used to measure the level of price dispersion. The first is the coefficient of variation (CV), defined as the ratio of the standard deviation to the mean. The second is the normalized price range (RNG), defined as the price range (MAX - MIN) divided by the mean. Summary statistics on the coefficient of variation and the normalized price range for these products are provided in Table 1.

In addition to these summary statistics, figure 6 provides a histogram of the distribution of the coefficient of variation and normalized price range. From these statistics and figures, it is clear that price dispersion, as measured, is a widespread phenomenon. The average coefficient of variation is 69 percent, the minimum 0, and over 95 percent of the products examined have more than 16 percent variation. The normalized price range provides a similar picture, the average is 398 percent, the minimum is 0 and over 95 percent have more than 68 percent price range.

It is also clear that there is an large tail to the distribution of price variation, as measured by the coefficient of variation and normalized price range. The maximum coefficient of variation if 1712 percent, and over 5 percent of the products have more than 226 percent variation. Similarly, the maximum price range is 42,429 percent and over 5 percent have more than 1300 percent price range. These latter results clearly indicate that something is wrong with these measures of price dispersion -- one would not expect any homogeneous product to have such a large variation in prices across producers. Either there are many poorly defined products or there are a significant number of errors in these data.

An examination of this price data for a single industry, the hydraulic cement industry, see Abbott (1988), revealed that the Census value and quantity data contain two types of errors which would affect our measure of dispersion: gross outliers and imputed data.

The first error is that of gross outliers; that is data which the Census Bureau's industry analyst believed to be incorrect. For example, in an industry with 60 producers, 59 producers sold the product at a price between $20 and $20 per ton while the remaining producers sold at a price of $250. Clearly there is a units problem with the reported data.[18] These types of errors occur in about 2 to 3 percent of the data and are most likely the result of reporting or keying errors.

The second type of data error is caused by imputations, observations for which missing data were replaced with an imputed a value based on the industry averages. A basic fact of working with Census data is that it is collected, edited, and maintained for the purposes of constructing aggregate statistics; not for the purpose of microeconomic analysis. As such, audit trails to specific microdata items are not well maintained and there is often no way to determine if a particular observation has been imputed, edited, or n original reported item.[19]

One method of dealing with the problem of gross data errors would be to "clean" the data and remove the individual observations which are deemed erroneous. In addition to the obvious selectivity problems induced by such a procedure, with over 112,000 observations such cleaning would be a laborious task. Moreover, if one attempted to automate the process by eliminating all observations which were more than X standard deviations from the mean, one would necessarily bias the estimated measure of dispersion downwards since the standard deviation of the truncated distribution is a downward biased estimate of the population parameter.

An alternative method for handling the grow error problem would be use of statistics which are robust to the presence of these errors, as discussed by Hempel et al. (1986) and Abbott (1989).[20] Under additional assumptions about the distribution of the actual prices, one can use order statistics to obtain robust estimates of the mean and standard deviation needed to construct the coefficient of variation. For example, under the assumption that a distribution is not skewed, the median provides a robust measure of the mean.[21] Further, assuming normality the interquartile range is approximately 1.348 times the standard deviation.[22]

The proposed statistic is the ratio of the interquartile range to the median, scaled to be comparable to the coefficient of variation,

(15) $RD = (Q_3 - Q_1) / (1.348 * Q_2)$.

Abbott (1989) shows that this statistic is robust for small samples, in the sense that the extent of the bias introduced by a single erroneous observation does not depend on the magnitude of the observation. Using this measure we reexamine the Census data as shown in Table 1. The average level of dispersion falls to 55 percent, the minimum is 0 percent, and over 75 percent of the products have more than 10 percent price variations. Although these statistics are substantially lower than those found with the conventional coefficient of variation, they still suggest that the unique price theory does not apply to most of the 7-digit products examined. A similar picture is presented in figure 6, where the entire distribution of the measure is shifted to the left in comparison with the coefficient of variation.

As shown in the figure, there is still a significant tail to the distribution of dispersion across producers (the last bar on the right indicated the proportion of the sample in the upper tail), with 5 percent of the RD statistics having greater than 90 percent dispersion. Thus, even the robust statistic is not impervious to gross errors in the data. That is, if there is a sufficient number of errors for a single product the RD measure will not provide an accurate measure of the underlying dispersion.[23] Thus, the tail of the RD distribution indicates that in some cases the data was just too dirty, or that the products were just poorly defined for even our robust measure.

Table 2 presents a list of the 20 products with the highest price dispersion, as measured by RD. From this list, it appears that these products are a mixture of "other" and "NEC" (Not Elsewhere Classified) products which did not conform to the usual principles used in defining the 7-digit SIC codes. Thus, it is not surprising that there should be such a wide range of reported prices for these product classifications. This evidence suggests that the tail of observed dispersion is caused by a failure of product definition rather than dirty data.

The third table examines price dispersion across two digit industrial groups using those products with less than 80 percent dispersion (RD). This truncation is used to remove the affects of the outlier products and leaves a 2,278 products for the analysis. From this table it is clear that although the average level of price dispersion differs across the major groups, price dispersion is a general phenomenon regardless of which measure is used. Thus, results presented in Table 1 and Figure 6 are not dominated by an particular industrial group and the potential problems in measuring real output exist in every industry.

IV. PRICE DISPERSION AND PRODUCT QUALITY

In this section, we explore the classic product quality explanation for observed price dispersion. We begin our discussion of product quality by making an assumption that product quality is a universal standard in which all consumers agree on the ranking of all products - that is, in the words of Tirole (1988), quality represents Vertical Product Differentiation in that "all consumers agree over the most preferred mix of characteristics and, more generally, over the preference ordering." [24] For example, in a market with three goods (A, B, C), if at the same price, all consumers rank A > B > C then we can say that A is of higher quality than B or C. If, however, some individuals prefer either B or C to A (at constant prices) then we cannot say which is of superior quality and must look for alternative explanations for individual consumer preferences.

Under the assumption of homogeneous preferences, complete information, and competitive markets, it is clear that if all three goods are sold then they must provide consumers with identical utility (net of the product price.) Therefore, $P_A > P_B > P_C$ and the differences in prices between the three goods must exactly equal the marginal utility of the additional quality. This framework serves as the basis for the hedonic price literature, which attempts to elate the price of the product to a bundle of characteristics which measure the quality of the product in several dimensions -- such as horsepower, mpg, and seating capacity for automobiles; or square feet, number of bathrooms, and number of fireplaces for houses, see for example Griliches (1971), Rosen (1974) and Dulberger (1988). Thus, competition across the different products drives the price differential across competing brands to reflect the differences in the utility of each bundle of characteristics.[25] Unfortunately, in order to implement this approach, one must identify and measure the underlying characteristics of each product, and determine the functional form of the hedonic price equation.

A more general approach can be obtained from looking at the production process itself. If, in addition, we made an assumption that differences in product quality can only result from differences in resources embodied in the product, we conclude that a Cadillac is a "better" care than a Ford because the Cadillac embodies more materials, energy, labor, and capital. Moreover, under the competitive assumptions, firms compete in both price and quality until the differentials between the quality of the product just equals the marginal cost of producing that additional quality. As in Waterson (1984), letting T_i represent a quality index (defined to be multiplicative with her values of T representing higher levels of quality), and returning to the case of a common technology and one product per firm, we characterize the production relation as

(16) $T_iQ_i = F(K_i,L_i,E_i,M_i)$,

where Q_i is the quantity of output, K_i is the quantity of capital services, L_i is the quantity of labor services, E_i is the quantity of energy, and M_i is the quantity of materials.

Assuming a Cobb-Douglas production function, and using lower case letters to denote the natural logs, we can re-write this production relation as

(17) $(t_i + q_i) = a_o + a_l k_i + a_2 l_i + a_3 e_i + a_4 m_i + u_i$,

Unfortunately, in applied word we frequently do not directly observe the quality index or the quantity of production, but instead observe only the value of sales (V). Letting $q_i = v_i - p_i$, and substituting, we find that

(18) $(t_i + v_i - p_i) = a_o + a_l k_i + a_2 l_i + a_3 e_i + a_4 m_i + u_i$,

(19) $v_i = (p_i + t_i) + a_o + a_l k_i + a_2 l_i + a_3 e_i + a_4 m_i + u_i$,

where the term in parentheses is generally omitted in the estimation of the production function leading to biased estimates as discussed in Abbott (1991).

Although, the technology index is not directly observable under the competitive conditions discussed above, it can be written as a function of price. Letting

(20) $T_i = \$ P_1^{"}$,

then under the standard assumption that price differences reflect differences in product quality, " should equal 1 (note that $\$$ is an arbitrary normalization for the technology index.) Under the alternative hypothesis of no quality differences across producers, " should equal 0 - thereby making T_i a constant. Taking logs, and substituting for t_i in equation 19 yields our estimation equation.

(21) $v_i = a_o + (1 - ") p_i + a_l k_i + a_2 l_i + a_3 e_i + a_4 m_i + u_i$,

Thus, cross sectional estimates of equation (21) provide a direct test of the hypothesis that the observed prices reflects qualitative differences through the coefficient on observed prices. In this equation, if the observed prices are proportional to product quality one would expect the coefficient of the price variable to be zero (i.e., " = 1.0). However, if there are no differences in product quality and real prices are measured correctly by our observed prices, one would expect a coefficient of 1.0 for the price variable (i.e. "= 0). Finally, if the observed prices are measured with error (or there are some differences related to product quality), the coefficient should be between zero and one reflecting an intermediate value for ".

Unfortunately, in order to conduct this test, one needs to collect all of the additional data necessary to estimate the production function. As an application of this approach, we examined the hydraulic cement industry because (1) it was near the median level of price disperison and (2) it is frequently used in the literature as an example of a homogeneous product. Despite the latter comment, we discovered that the Bureau of the Census actually collected data on nine different hydraulic cement products -- details on the construction of the establishment level data set used in this paper can be found in Abbott (1991).

Since our above theory of product quality is articulated in a single product environment, it is important to establish that a valid aggregate exists for this industry. A preliminary analysis of the establishment-product prices showed that the assumption of constant relative prices across products (but different price levels) was not unreasonable. Empirical work presented in Abbott (1988) estimated a model which represented the establishment-product price at time t as the product of an establishment component (held fixed across all products) and a product component (held fixed across all establishments), i.e.

(22) $\ln(P_{ijt}) = E_i\, I_j\, b_{jt} + u_{ijt}$,

where I_i is an indicator for establishment i, I_j is an indicator for product j, and u_{ijt} is an error term. This model resulted in an R-square of about .8, indicating that the assumption of fixed relative prices (of the different products) across establishments was not a bad approximation. Thus, we can apply Hicks' aggregation theorem to establish that sales is a valid measure of aggregate output at the establishment level. In this case, the p_{it} coefficient can be interpreted as the log of the price index for establishment i in period t, and b_{jt} interpreted as the mark up in period t of the product j over the numeraire good, subject to the normalization that $b_{1t} = 0$. In our analysis, "Normal Portland Cement - ASTM Type I" (SIC 3241012) was chosen as the numeraire good since this product was produced by nearly every plant and it represented over 63 percent of the total value shipments for the industry.

Table 4 compares the OLS and 2SLS estimates of equation (21) where the 2SLS estimator is used to over come both measurement errors in the individual prices as well as any simultaneity between the individual firm price and their level of output.[26] Using data for a sample of 40 establishments in this industry, we found that the OLS results clearly show that the price coefficient is significantly different from zero, rejecting the hypothesis that the individual prices are proportional to differences in product quality. The 2SLS estimator, presented in column 2, however, was unable to support the same conclusion - even though the point estimate has increased and is almost exactly the predicted value of 1.0 -- because of the high standard errors associated with this estimator. This finding could be the result of the small sample size and/or weak instruments. The results of a more complete analysis, pooling data from 1972, 1977, and 1982 are provided in the last column. In this analysis, the 2SLS estimator clearly rejects the product quality interpretation in favor of a finding of real price dispersion.[27]

Although one must be careful not to generalize these results to the other industries examined in section III of this study, it does suggest that the issue of price dispersion is worthy of further consideration, and that the standard response that price differences are due to product quality is not universally accepted.

V. CONCLUSIONS

The analysis presented here establishes two important empirical facts concerning price dispersion in U.S. Manufacturing. First, we found that measured prices varied a great deal across producers, even at the 7-digit product level. Second, we found that this price dispersion was not isolated to a few manufacturing industries but exists, to some extent, in all industries. The analysis establishes these results using <u>all</u> of the product data available in the 1982 Census of Manufactures. These facts clearly run counter to the assumption of a single homogeneous good and perfect competition usually made in analyzing economic behavior at either an industry or firm level.

The basic data used to arrive at these conclusions, however, suffer from two types of errors: gross outliers and imputed data. The gross errors bias the estimated dispersion upwards and are addressed through the use of robust statistics. The imputations, on the other hand, bias the estimated dispersion downwards and their affects cannot be easily eliminated from the data.[28] As a result, the current analysis only provides information on whether or not individual products exhibit price dispersion and does not provide reliable comparisons of the level of price dispersion across different products or industries.

Having established these facts, one must proceed to address two additional questions: What is the underlying source of the observed price dispersion? and does price dispersion imply market power? For the hydraulic cement industry, we found that we could reject the assertion that the observed price dispersion was the result of differences in product quality. In a more complete study of this industry, Abbott (1990) was able to demonstrate that the observed price dispersion was related to local conditions in both the output and input markets; and that manufactures did in fact possess market power (defined as being able to pass through individual factor price increases). Considering the nature of the industry, these findings are not surprising. It remains to be seen as to whether similar conclusions can be established for other industries or whether the cement industry is unique in this respect as well.

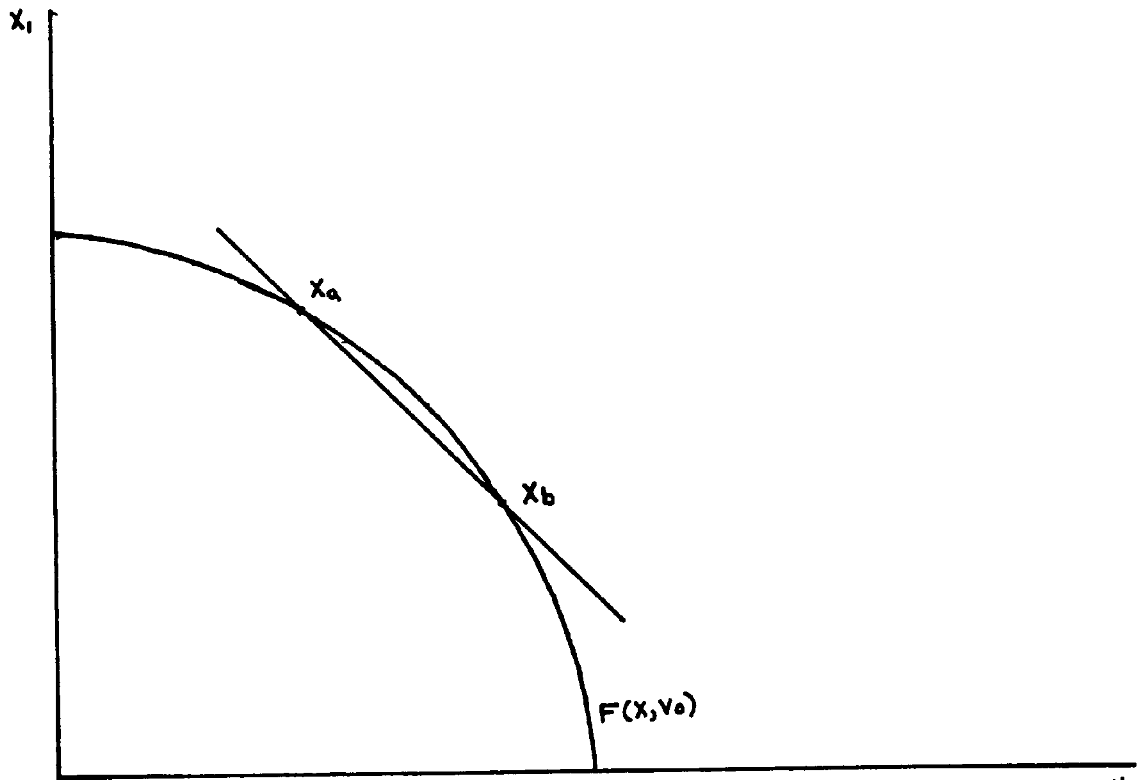


Figure 1

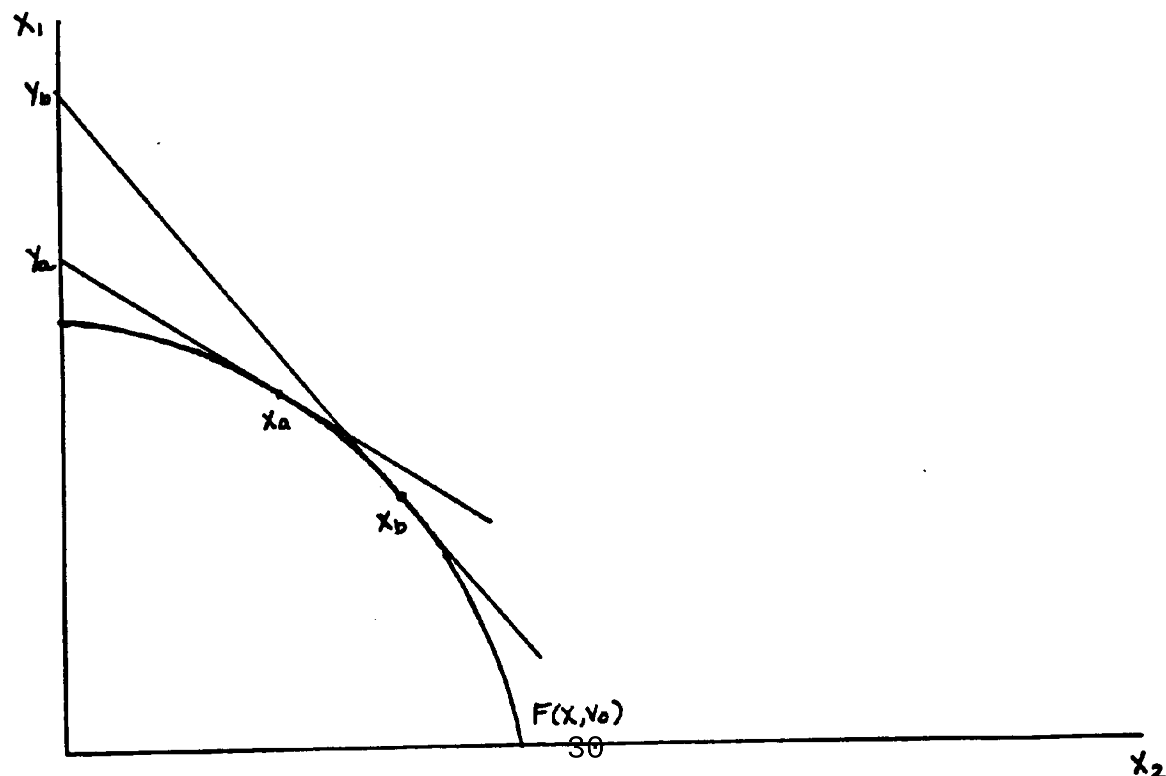


Figure 2

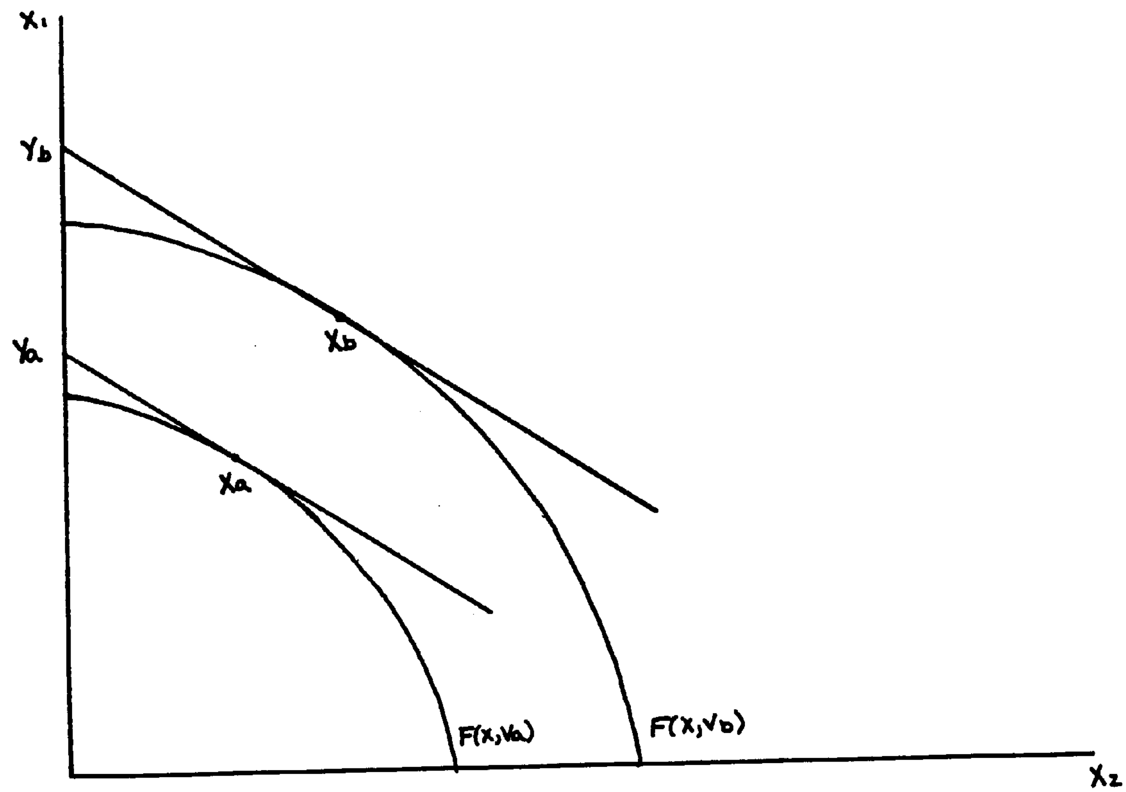


Figure 3

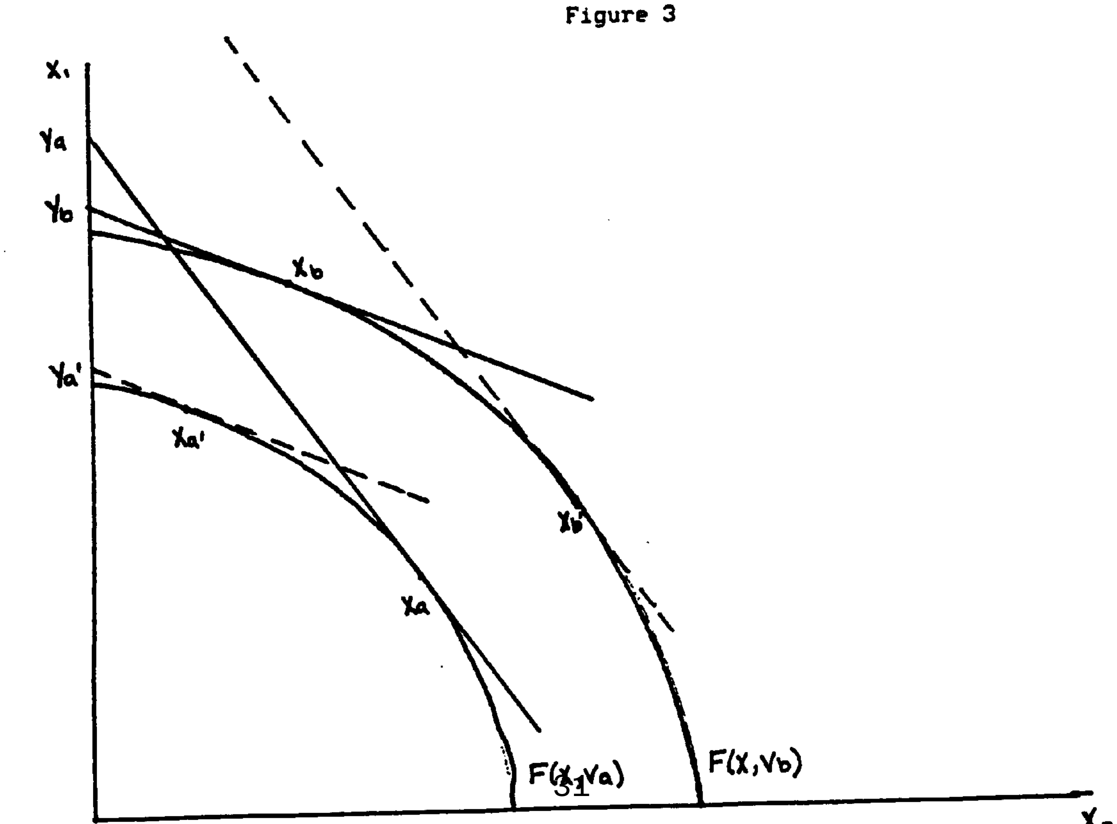


Figure 4

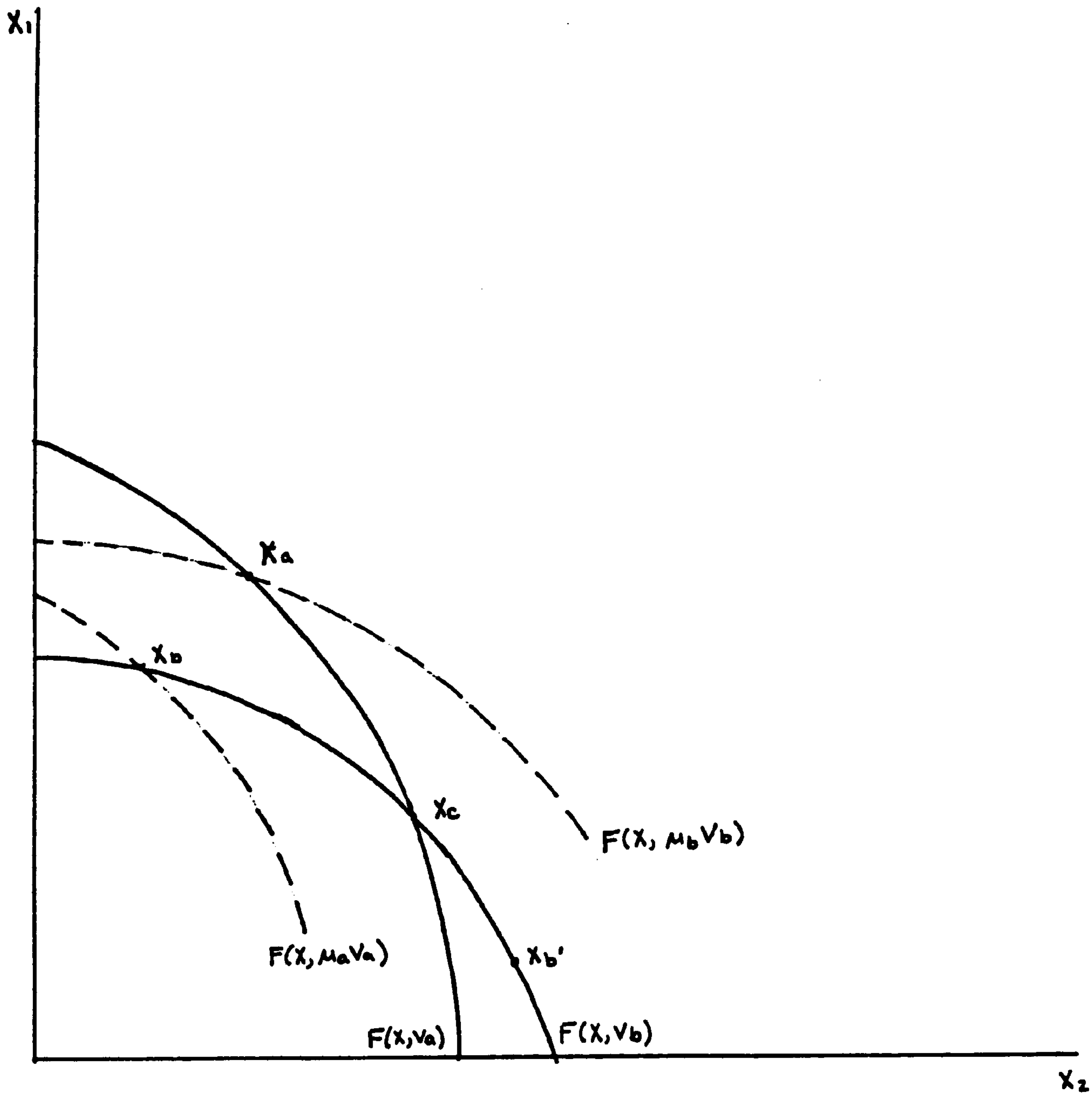
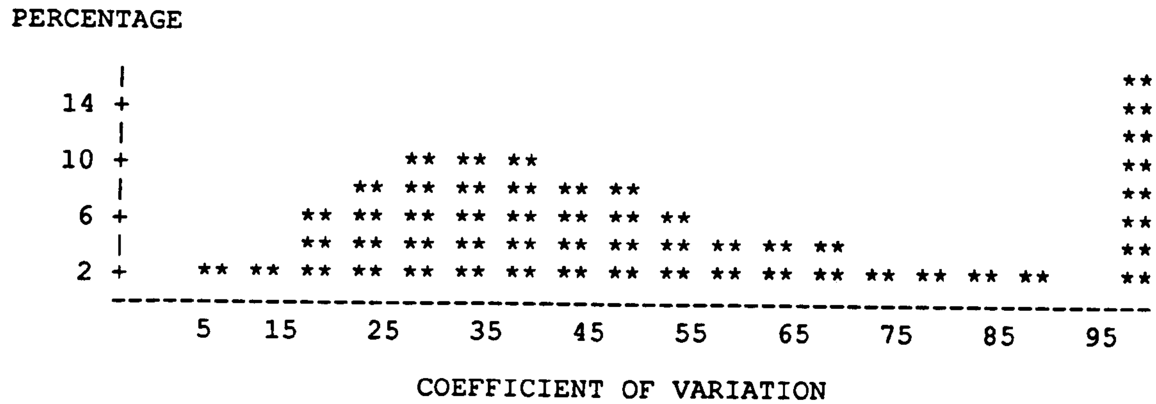
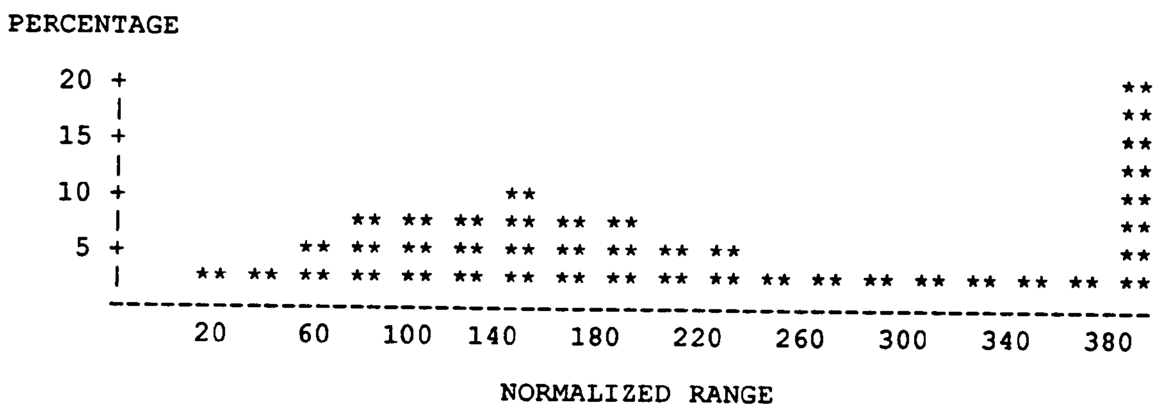
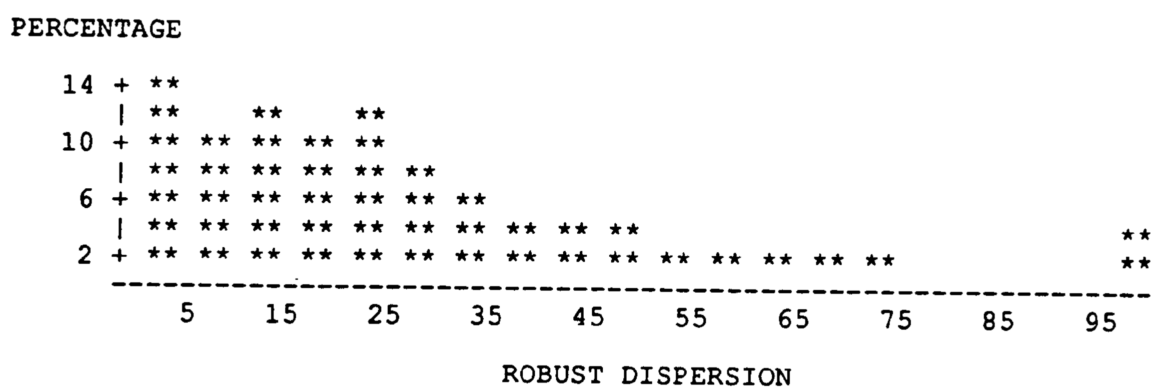


Figure 5

Figure 6: Measures of Price Dispersion







Please note that the column at the end of each graph represents the proportion of the data found beyond the last point on the graph.

Table 1:

Measures of Price Dispersion

	Coefficient of Variation	Normalize Range	Robust Dispersion
N	2430	2430	2430
Mean	69.4	398	55.4
Quantiles			
100% Max	1712	42430	39985
99%	512	3889	237
95%	225	1300	91
90%	135	736	65
75% Q3	65	310	38
50% Med	42	183	21
25% Q1	29	124	11
10%	20	85	1.5
5%	16	68	0.09
1%	8	35	0.002
0% Min	0	0	0

Table 2:

Individual Product Price Dispersion

Product #	RD	Product Description
2392045	39985	Other Household furnishings - Napkins
2099967	8796	Perishable Food Products - Tortillas, Tamales, and other Mexican Specialties
3079030	2813	Misc. Plastic Products - Plastic Bottles
3131061	1834	Footwear Cut Stock - Other boot & shoe cut stock and findings
3079065	1657	Molded Plastic Products NEC - castings
2421896	1351	Softwood Flooring and Siding - other planing mill and sawmill products
2899597	1193	Essential Oil, Fireworks and Chemical NEC - other industrial chemical specialties plastic wood preparations and embalming chemicals
3079061	815	Molded Plastic Products NEC - injection molding
3691411	791	Storage Batteries, Lead Acid Type - Industrial Truck
3691419	706	Storage Batteries, Lead Acid Type - other motive power
2257820	667	All other Weft Knit Fabric - narrow fabrics under 12" wide
3873126	566	Clocks (not having balance wheel and hairspring) - all other including chime and strike
3551221	529	Commercial Food Products Machinery - Choppers, Grinders, Cutters, etc.
3494640	496	Hydraulic and Pneumatic Hose or Tube End Fittings and Assemblies except Aerospace
2851951	432	Miscellaneous Paint Products - Organosols and Plastisols, other than coatings
2599097	400	Furniture and Fixtures NEC - Other NEC except household
2299340	396	Scouring and Combing Mill Products - Tops and Noils
3634510	357	Electrical Housewares and Fans - Small household appliances, including razors
2599021	345	Furniture and Fixtures NEC - Hospital Beds

3079094	338	Miscellaneous Plastic Products - Building and Construction
3312192	299	Blast Furnace Products - Slag
3079066	298	Molded Plastic Products NEC - Other
3799988	286	Transportation Equipment NEC - Parts for Automobile and Light Truck Trailers
2843085	249	Surface Active and Finishing Agents - Bulk Surface Agents (detail reported ITC)
2299350	237	Scouring and Combing Mill Products - Scoured wool and other products

Table 3

Two Digit Industry Price Dispersion
All Industries

Major Group		Number of Products	Average CV	Average RNG	Average RD
20	Food and Kindred Products	590	46.532	247.511	125.731
21	Tobacco Manufactures	7	46.409	187.267	31.249
22	Textile Mill Products	101	70.191	332.998	37.619
23	Apparel and Other Textiles	76	122.851	926.101	33.598
24	Lumber and Wood Products	143	70.675	666.787	14.330
25	Furniture and Fixtures	65	83.949	509.331	18.608
26	Paper and Allied Products	105	44.676	300.196	15.596
27	Printing and Publishing	94	105.513	876.306	30.596
28	Chemicals and Allied Products	179	55.886	275.694	24.099
29	Petroleum and Coal Products	47	89.435	521.475	20.024
30	Rubber and Plastic Products	34	62.122	283.529	16.549
31	Leather and Leather Products	25	80.961	452.479	30.230
32	Stone, Clay and Glass Products	86	74.368	490.113	18.481
33	Primary Metal Industries	107	66.430	330.023	27.633
34	Fabricated Metal Industries	269	64.602	378.892	17.645

35	Machinery, Except Electrical	154	58.636	279.295	19.821
36	Electric & Electronic Equipment	28	76.963	328.27	126.455
37	Transportation Equipment	76	81.192	440.681	33.087
38	Instruments & Related Products	29	73.577	265.709	24.625
39	Misc. Manufacturing	63	79.570	376.052	24.196

Table 4

Production Function Estimates

Dependent Variable: Log of Total Value of Production

	1982 - OLS	1982 - 2SLS	Pooled 2SLS
Intercept	-1.8222	-3.3610	Time
	(1.1080)	(3.0370)	Dummies
	***		***
Price	0.5718	0.9862	0.2334
	(.1638)	(.6771)	(.0719)
			***
Capital	0.1289	0.1371	0.2334
	(.1302)	(.1361)	(.0719)
	*		
Labor	0.2689	0.2635	0.0963
	(.1515)	(.1884)	(.0826)
	***	***	***
Energy	0.5119	0.4992	0.5283
	(.1166)	(.1380)	(.0778)
	***	***	***
Materials	0.2509	0.2470	0.2262
	(.0724)	(.0824)	(.0452)
N	40	40	120
RSq	0.836	---	---
SER	0.234	0.284	0.245

* Significant at 10 percent level
** Significant at 5 percent level
*** Significant at 1 percent level

APPENDIX

Let,

$$Q_t = E_i\ S_{it}/D_t$$
$$\mathcal{Q}_t = E_i\ S_{it}/\mathcal{D}_t$$

Then,

$$\mathcal{Q}_t/Q_t = (E_i S_{it}/\mathcal{D}_t) / (E_i S_{it}/D_t)$$

$$= D_t/\mathcal{D}_t$$

But, from equation (7)

$$\mathcal{D}_t = E_i P_{it} * \{(S_{it},/S_t,) * (\mathcal{D}_{t-1}/p_{it}-1)\}$$

Thus,

$$\mathcal{Q}_t/Q_t = D_t/[E_i P_{it} * \{(S_{it},/S_t,) * (\mathcal{D}_{t-1}/p_{it}-1)\}]$$

$$= (D_t/\mathcal{D}_{t-1}) * (1/[E_i\ (P_{it}/P_{it-1}) * (S_{it},/S_t,)])$$

substituting,

$$*_{it} = P_{it}/P_{it-1} \text{ and } N_{it}, = S_{it},/S_t,$$

we get

$$\mathcal{Q}_t/Q_t = (D_t/\mathcal{D}_{t-1}) * (1/[E_i *_{it} * N_{it},])$$

Combining the well known statistical result that

$$E\ A * B = N\ Cov(A,B) + E\ A\ E\ B / N$$

with the fact that

$$E\ N_{it}, = 1$$

we arrive at

$$\mathcal{Q}_t / Q_t = (D_t / \mathcal{D}_{t-1}) * (1 / N\ Cov\ (*_{it}, N_{it},) + E_i *_{it}/N)$$

$$= (D_{t-1}/\mathcal{D}_{t-1}) * (D_t/D_{t-1}) / (N\ Cov(*_{it},N_{it},) + E_i *_{it}/N)$$

which is given in the text as equation (8) on page 5.

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Notes

1. In a related paper, Lichtenberg and Griliches (1989) discuss the effects of error in the measurement of output deflators at the aggregate level on the measurement of long term productivity growth. In contrast, this paper focuses on the cross sectional effects of using aggregate deflators for individual firms or establishments.

2. Recall that for the direct aggregation of goods, Hicks Aggregation Theorem requires that the goods either be produced (or consumed) in fixed proportions or that relative prices remain constant. In the case where individual producers have different market segments and are able to adjust prices to segment specific market conditions, the assumption of constant relative prices is untenable and direct aggregation is therefore not valid. In most empirical studies, sales (a direct aggregate) is the basis for the measure of total production.

3. It is important to note that some of the studies cited were conducted with objectives other than showing the existence of price dispersion and questioning the assumption of a single market price. For example, Stigler-Kindahl's work primarily focused on showing that in order to obtain accurate aggregate price deflators, BLS should follow prices from many different producers and did not focus on an explanation for why different producers received different prices.

4. The Standard Industrial Classification system (SIC) was established in the late 1930's to provide a method for the classification and aggregation of industrial statistics in the United States (see U.S. Office of Management and Budget (1972) for additional details). The SIC system is composed of an ordered number scheme similar to the Library of Congress's classification of published material by subject matter. The first two digits of the SIC code are used to designate major industrial groups (e.g., Textile Mill Products (22) and Stone, Clay, and Glass Products (32)). The next two digits are used to break out specific industries within these major groups (e.g., Cotton Textile Weaving Industry (2211) and the Hydraulic Cement Industry (3241)). Finally, individual products from these industries are given seven digit codes (e.g., Finished Cotton Broad Woven Fabrics - Bleached and White Finished (22117811) and

Normal Portland Cement ASTM Type 1 (3241012)). The Bureau of the Census collects some data at the 7-digit product level.

5. In some instances, researchers may want to use the measures of real output as an explanatory variable, as is estimating a labor demand equation or variable cost function. In this instance, the model will suffer from a more typical errors in variables problem, although the usual assumption of independent measurement errors may need to b replaced with a more sophisticated assumption. In certain circumstances, these problems may be overcome through the use of an instrumental variables estimator; although it should be pointed out that one must not instrument for q, but also for any variable on the right hand side that might be correlated with the individual price difference (i.e., the measurement errors in q).

6. It should be noted, that this is a Divisia type index (it is not a correct Divisia index because the share weights are held constant for some finite period of time rather than allowed to adjust to each period). It is well known that Divisia Indices satisfy a number of optimal properties, see Richter (1966), Hulton (1973), and Diewert (1976). However, these results are established in the context of the economy in competitive equilibrium. It is precisely the lack of such an competitive equilibrium which causes the problems which arise in this paper. Moreover, in the context of measuring real output over a sample of firms, the Divisia index approach is totally inappropriate because the index is path dependent; implying that if the order of firms changes, the "real" output index number for each firm will also change.

7. Please note that price relatives are used to eliminate the heterogeneity problem and implicitly assume that all of the products within the industry undergo the same inflationary and productivity changes.

8. An argument can easily be made in the other direction as well, as firms which are temporarily experiencing increased demand raise bother their price and volume while firms experiencing a slowdown attempt to attract additional customers by lowering their prices even further.

9. Please note that while Figures 1-4 are not taken directly from Fisher-Shell (1972), they are certainly inspired and influenced by their work and do not represent original contributions on the part of this author. They are presented in this text for expository purposes only.

10. If, however, the firm is not producing at the competitive equilibrium point because, for example, prices are not exogenous

to the firm; the relative prices are not the appropriate measures of the marginal rate of product transformation.

11. See Chamber (1988) Chapter 7 for a comprehensive discussion of the properties of a multi-product production technology.

12. In section IX of their text, Fisher and Shell (1972) examine the case of changing factor supplies and factor augmenting technical change which could be similar to the case of figure 5, although they specifically rule out any economies of scope by assuming a production function for each output which is dependent only on the level of inputs assigned to that product, and is independent of the level of the other outputs. While this may make sense for examining the output of the economy as a whole, economists usually believe that the reason why products are grouped together in a firm or industry is that there are economies of scope in providing these products jointly. Thus the Fisher-Shell analysis can not be applied to the situation under examination in this paper.

13. In fact, Fisher and Shell argue that these two methods of computing the indices will only be compatible in the case of homothetic technologies; a case which is clearly ruled out if the two PPF's intersect.

14. Two examples which come to mind are (1) the change over from wet to dry processing in the manufacturing of cement starting in the early 1970-s, and (2) the introduction of the mini-mills in the manufacturing of steel products at about the same time. In both cases, manufactures currently compete using different technologies depending upon when their plants were put on line. On a more general note, if there are no differences in the mix of inputs across firms, one would have trouble identifying the parameters of the production function from cross sectional data.

15. In many instances the census does not collect quantity information due to the heterogeneity of the 7-digit product definition. In addition, to insure that the measured price dispersion was not the result of rounding errors, the sample was further restricted to only those plant-product observation with three or more significant digits.

16. The Sic classification system is set up so that a seven digit product ending in '00' is generally an NSK (not specified by kind) classification - that is the manufacturer did not report the specific product (seven digit code) that was being produced. Rather than contaminate the other data, these observations are pooled into one "general" category. Administrative Records are also frequently included in this NSK Classification.
Products ending in a '98' or '99' are generally NEC (not

elsewhere classified) product classifications. These products typically include a mixture of highly specialized products which get lumped together for purposes of data collection.
For an examination of price dispersion across "homogenous" products, the author felt the NSK and NEC products were clearly inappropriate for the analysis and could bias the results. Thus, they have been removed from the analysis.

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20. In general, a robust statistic is a measure which is not greatly influenced by small deviations in the basic assumptions. In this context, we are looking for a measure of the dispersion which is not sensitive to the magnitude of the gross errors.

21. The median is robust in that given a sample of observations, adding an erroneous observation to one of the tails results in only a small bias in the median (for example moving from the 50th to the 51st percentile) and more importantly, the extent of the bias does not depend on the size of the error (the erroneous observation could be at 1 standard deviation or 100 standard deviations, the impact on the median is the same; but clearly the impact on the mean is very different).

22. The finite sample properties of the median and interquartile range as measures of central tendency and variation are examined in Abbott (1989).

23. For example, suppose that there are 10 observations for a particular product and that of these 4 are erroneously reported at $100 while the remaining are tightly packed around $5. In this case, the interquartile range will be close to $95 since the 75th percentile of the data is at the $100. Errors like this would most likely indicated that the product is being produced in more than one industry and that the units of data collection differed across the two industries (for example tons verses 100s of pounds).

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25. Interestingly, empirical studies of hedonic prices frequently have to incorporate a dummy variable for one or more of the "leading" firms (the so-called IBM effect in computer prices). These firm dummies are typically interpreted as capturing the reputational affects of the firm. One might, however, interpret these as unexplained price variations as well.

26. The instruments included the individual establishment average wage rate, and an energy price index constructed at the establishment level.

27. A similar analysis has been conducted using the Translog production function and qualitatively identical results were found.

28. Some information on the dollar value of the imputation is obtainable from the individual industry summaries. This information has not been incorporated in the current study.

Notes

1. In a related paper, Lichtenberg and Griliches (1989) discuss the effects of errors in the measurement of output deflators at the aggregate level on the measurement of long term productivity growth. In contrast, this paper focuses on the cross sectional effects of using aggregate deflators for individual firms or establishments.

2. Recall that for the direct aggregation of goods, Hicks Aggregation Theorem requires that the goods either be produced (or consumed) in fixed proportions or that relative prices remain constant. In the case where individual producers have different market segments and are able to adjust prices to segment specific market conditions, the assumption of constant relative prices is untenable and direct aggregation is therefore not valid. In most empirical studies, sales (a direct aggregate) is the basis for the measure of total production.

3. It is important to note that some of the studies cited were conducted with objectives other than showing the existence of price dispersion and questioning the assumption of a single market price. For example, Stigler-Kindahl's work primarily focused on showing that in order to obtain accurate aggregate price deflators, BLS should follow prices from many different producers and did not

focus on an explanation for why different producers received different prices.

4. The Standard Industrial Classification system (SIC) was established in the late 1930's to provide a method for the classification and aggregation of industrial statistics in the United States (see U.S. Office of Management and Budget (1972) for additional details). The SIC system is composed of an ordered number scheme similar to the Library of Congress's classification of published material by subject matter. The first two digits of the SIX code are used to designate major industrial groups (e.g., Textile Mill Products (22) and Stone, Clay, and Glass Products (32)). The next two digits are used to break out specific industries within these major groups (e.g., Cotton Textile Weaving Industry (2211) and the Hydraulic Cement Industry (3241)). Finally, individual products from these industries are given seven digit codes (e.g., Finished Cotton Broad Woven Fabrics - Bleached and White Finished (22117811) and Normal Portland Cement ASTM Type 1 (3241012)). The Bureau of the Census collects some data at the 7-digit product level.

5. In some instances, researchers may want to use the measures of real output as an explanatory variable, as in estimating a labor demand equation or variable cost function. In this instance, the model will suffer from a more typical errors in variables problem, although the usual assumption of independent measurement errors may need to be replaced with a more sophisticated assumption. In certain circumstances, these problems may be overcome through the use of an instrumental variables estimator; although it should be pointed out that one must not only instrument for q, but also for any variable on the right hand side that might be correlated with the individual price differences (i.e., the measurement errors in q).

6. It should be noted, that this is a Divisia type index (it is not a correct Divisia index because the share weights are held constant for some finite period of time rather than allowed to adjust in each period.) It is well known that Divisia Indices satisfy a number of optimal properties, see Richter (1966), Hulton (1973), and Diewert (1976). However, these results are established in the context of the economy in competitive equilibrium. It is precisely the lack of such an competitive equilibrium which causes the problems which arise in this paper. Moreover, in the context of measuring real output over a sample of firms, the Divisia index approach is totally inappropriate because the index is path dependent; implying that if the order of firms changes, the "real" output index number for each firm will also change.

7. Please note that price relatives are used to eliminate the heterogeneity problem and implicitly assume that all of the

products within the industry undergo the same inflationary and productivity changes.

8. An argument can easily be made in the other direction as well, as firms which are temporarily experiencing increased demand raise both their price and volume while firms experiencing a slowdown attempt to attract additional customers by lowering their prices even further.

9. Please note that while Figures 1-4 are not taken directly from Fisher-Shell (1972), they are certainly inspired and influenced by their work and do not represent original contributions on the part of this author. They are presented in this text for expository purposes only.

10. If, however, the firm is not producing at the competitive equilibrium point because, for example, prices are not exogenous to the firm; then relative prices are not the appropriate measures of the marginal rate of product transformation.

11. See Chambers (1988) Chapter 7 for a comprehensive discussion of the properties of a multi-product production technology.

12. In section IX of their text, Fisher and Shell (1972) examine the case of changing factor supplies and factor augmenting technical change which could be similar to the case of figure 5, although they specifically rule out any economies of scope by assuming a production function for each output which is dependent only on the level of inputs assigned to that product, and is independent of the level of the other outputs. While this may make sense for examining the output of the economy as a whole, economists usually believe that the reason why products are grouped together in a firm or industry is that there are economies of scope in providing these products jointly. Thus the Fisher-Shell analysis can not be applied to the situation under examination in this paper.

13. In fact, Fisher and Shell argue that these two methods of computing the indices will only be compatible in the case of homothetic technologies; a case which is clearly ruled out if the two PPF's intersect.

14. Two examples which come to mind are (1) the change over from wet to dry processing in the manufacturing of cement starting in the early 1970's, and (2) the introduction of the mini-mills in the manufacturing of steel products at about the same time. In both cases, manufactures currently compete using different technologies depending upon when their plants were put on line. On a more general note, if there are no differences in the mix of inputs across firms, one would have trouble identifying the parameters of the production function from cross sectional data.

15. In many instances the Census does not collect quantity information due to the heterogeneity of the 7-digit product definition. In addition, to insure that the measured price dispersion was not the result of rounding errors, the sample was further restricted to only those plant-product observations with three or more significant digits.

16. The SIC classification system is set up so that a seven digit product ending in '00' is generally an NSK (not specified by kind) classification - that is the manufacture did not report the specific product (seven digit code) that was being produced. Rather than contaminate the other data, these observations are pooled into one "general" category. Administrative Records are also frequently included in this NSK classification.

Products ending in a '98' or '99' are generally NEC (not elsewhere classified) product classifications. These products typically include a mixture of highly specialized products which get lumped together for purposes of data collection.

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