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Abstract:
This paper explores the inconsistency of common scale estimators when output is proxied by deflated sales, based on a common output deflator across firms. The problems arise when firms operate in an imperfectly competitive environment and prices differ between firms. In particular, we show that this problem reveals itself as a downward bias in the scale estimates obtained from production function regressions, under a variety of assumptions about the pattern of technology, demand and factor price shocks. The result also holds for scale estimates obtained from cost functions. The analysis is carried one step further by adding a model of product demand. Within this augmented model we examine the probability limit of the scale estimate obtained from an ordinary production function regression. This analysis reveals that the OLS estimate will be biased towards unity - or possibly a value below unity. We have included an empirical section which illustrates the issues. The empirical analysis presents a tentative approach to avoid the problems discussed in the theoretical part of this paper.

Keywords: Scale economies, imperfect competition, econometric misspecification, price heterogeneity.

JEL classification: C23, D24.

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1 Introduction

In many, if not most branches of economics there is a renewed interest in questions related to scale economies and imperfect competition. Despite its long history, empirical estimation of scale economies remains a controversial and unsettled research topic. In particular, scale estimates obtained by estimating production functions on the basis of firm level data tend to suggest substantial decreasing returns to scale[1]. On the other hand, it is well known that estimates of factor demand equations give results which imply increasing returns to scale[2]. This paper points out a common problem with scale estimates obtained from both production function and cost function regressions. In particular, we suggest that the coefficients usually interpreted as the scale elasticity in such regressions, more generally should be considered a mixture of both the scale elasticity and demand side parameters.

The large amount of heterogeneity between firms, even within narrowly defined industries, is one of the clear facts which have emerged from the many studies of firm behavior based on micro data sources. For instance, significant dispersion in output prices seems to exist between firms in several industries (see studies cited below). This paper explores one implication of neglecting such price dispersion. The theoretical part of this paper shows that the practice of using deflated sales as a proxy for real output will *ceteris paribus* tend to create a downward bias in the scale estimate obtained from production functions regressions. This is so under a variety of conditions if the firms face an imperfectly competitive environment. When estimating cost functions - which is closely related to estimating factor demand equations - we show that there will be a similar bias. The basic issue we are addressing in this paper was clearly recognized already by Marschak and Andrews (1944), but seems to have been neglected in much of the later literature on empirical production analysis.

The analysis is carried one step further by adding a model of product demand to the model of producer behavior. Within this augmented model we examine the bias in the scale estimate

[1] This proposition summarizes the studies which apply panel data; see e.g. Cuneo and Mairesse (1984), Griliches and Mairesse (1984, 1990). Cross sectional studies of production functions typically suggest increasing returns to scale; see e.g. Griliches and Ringstad (1971) and Ringstad (1974). There is a widely held view that scale estimates from cross sectional studies are upward biased as these studies do not account for persistent differences in efficiency between firms. This is an old issue which is much commented on in the literature. Discussions of the questions involved in comparing cross sectional and panel data studies of production functions are provided by e.g. Ringstad (1971), Mundlak (1978), Griliches and Mairesse (1990) and Mairesse (1990).

[2] Griliches and Hausman (1986) examine to what extent increasing returns to scale in the labour demand equation can be interpreted as errors in variables in the output variable.

obtained from an ordinary OLS-regression of the production function. This analysis consider both the bias caused by replacing output by deflated sales, as well as the bias caused by the correlation between input growth and productivity shocks (often termed the "transmission bias"[3]). On the basis of this augmented analysis, we show that the scale estimator is biased towards unity - or possibly to a value below unity.

The empirical part of this paper is meant to illustrate the issues pointed out in the theoretical sections. In particular, we present a tentative approach to consistent estimation of price cost margins and scale economies when deflated sales is the available proxy for real output. One of the main points of this analysis is to show how the parameters in "production function regressions" are reduced form parameters, i.e. mixtures of supply and demand side coefficients. The analysis presents assumptions sufficient to permit us to recover the price cost margin and the elasticity of scale from production function and cost function regressions, after we have added changes in average sales as an additional regressor. After reinterpreting the estimated parameters as reduced form coefficients, we find estimates of the scale elasticity to variable factors alone of the order 1.06 – 1.10, and estimated demand elasticities which vary from -6 to -12.

The empirical analysis is related to a more general issue. Our regressions reveal that total factor productivity at the plant level is highly correlated with the (industry-wide) changes in average sales, in regressions where we do not impose assumptions about constant returns to scale or perfect competition. Hall (1990) has provided an extensive discussion of the possible explanations for the procyclical behavior of total factor productivity. Two explanations examined in great detail by Hall are market power and scale economies. Our results suggest that, at the micro level, the procyclical movements in (measured) productivity can not be fully accounted for by incorporating imperfect competition and scale economies into the model[4].

Abbott (1991) has presented results supporting the perspective of the current paper. He had access to price data for individual firms (which we do not have). His analysis shows that

[3]The literature on the "transmission bias" dates back to Marschak and Andrews (1944). This simultaneity problem has been discussed by Mundlak and Hoch (1965) and Zellner et al. (1966) among others.

[4]The empirical model presented in the second half of this paper is very similar to a model examined by Bartelsman, Caballero and Lyons (1991). Their main finding is that productivity at the industry level is highly correlated across industries, and in particular with changes in output aggregated across industries. The current paper identifies a similar pattern at the plant level. However, the interpretation we offer differ entirely from the interpretation of Bartelsman et al., who claim their finding suggests some kind of external economies. We interpret our finding as a result of the econometric problem created by replacing the unobserved movements in output with changes in deflated sales.

prices differ significantly within the hydraulic cement industry in the U.S., also after adjustment is made for differences in output mix. Using individual deflators rather than industry wide deflators gives different, and in Abbott's terms, more plausible estimates of production function parameters and productivity changes. Dunne and Roberts (1992) also emphasize the importance of price dispersion between firms within narrowly defined industries. Having access to firm level price data, they examine to what extent price differences can be explained by cost differences as well as variables capturing the firm's competitive environment.

This paper is organized as follows: Section 2 provides a general theoretical analysis of the problem created by using a common deflator when prices differ between firms, in terms of the omitted variable framework. It begins by examining the production function case, and then provides a discussion of the cost function case. Section 3 carries the analysis a step further in the production function case, by studying an explicit, complete framework of supply and demand. The asymptotic bias in the OLS scale estimator is derived assuming orthogonality between the idiosyncratic productivity, markup, factor price and demand shocks. Some extensions are also considered. The empirical analysis is presented in section 4. Some final remarks are added in section 5.

2 The omitted variable bias

In this section we will provide a general analysis of the inconsistency of scale estimates when estimation proceeds by using deflated sales instead of output in production and cost function analysis. The analysis shows that if the (real, unobserved) prices are correlated with the included variables in the model, an omitted variable bias will arise. More specifically, we will argue that in the analysis of production functions, plausible assumptions suggest that commonly applied scale estimators will be downward biased. Also in the case of cost functions a similar bias of the scale elasticity will occur. To focus ideas we will carry out the argument in terms of panel data estimation of production relationships. More specifically, we will consider models in terms of growth rates, but the argument can easily be altered to be of relevance for pure cross sectional regressions. However, the biases will probably differ, as the *importance* of the various shocks considered below will be different in the cross sectional versus the time series dimension.

2.1 The production function case

Let us assume that the true production function relationship can be written

$$q = X\alpha_0 + u^q, \tag{1}$$

where q is a $(N \times 1)$ - vector of the growth in "real" output, X is a $(N \times L)$ matrix of the growth in inputs. α_0 is the $(L \times 1)$ vector of the parameters of interest, while u^q is assumed to be an orthogonal error term. N is the number of observations. The model in equation (1) is the familiar Cobb-Douglas production function, and the scale elasticity is defined as; $\epsilon \equiv \sum_{i=1}^{L} \alpha_{i0}$.

The estimated model is a slight modification to equation (1):

$$r = X\alpha + u^r, \tag{2}$$

where the left hand side variable now is r, which represents changes in deflated sales based on an industry wide deflator. The OLS estimator of the parameter vector α, assuming orthogonality of u^r, is

$$\hat{\alpha} = (X'X)^{-1}X'r. \tag{3}$$

Define the growth in the firm specific price relative to the deflator as π. Then the relationship between true output (q) and deflated sales is $\pi + q = r$. Focusing on the probability limit of $\hat{\alpha}$, and using this relationship, we obtain

$$\text{plim}_{N\to\infty}(\hat{\alpha}) = \alpha_0 + \text{plim}_{N\to\infty}[(X'X)^{-1}X'\pi)] + \text{plim}_{N\to\infty}[(X'X)^{-1}X'u^q]. \tag{4}$$

Both of the last two terms in equation (4) may have non-zero probability limits. The potential non-zero probability limit of the last term in equation (4) is referred to in the literature as the bias from the "transmission" of productivity shocks (Cf. footnote 3). This problem will be neglected for the moment, as it has been discussed extensively in the existing literature. Let us focus on the second term on the right hand side of equation (4).

To examine the second term in equation (4), notice that it can be expressed as the OLS-estimate of the vector of $\delta's$ in the following auxiliary regression[5]:

[5]This idea has been applied by Griliches (1957), and Griliches and Ringstad (1971, appendix C) to discuss other issues of specification bias in the estimation of production functions.

$$\pi = X\delta + u^{\pi}, \tag{5}$$

where u^{π} is an orthogonal error term. The direction and the size of the bias in $\hat{\alpha}$ will depend on the sign and the magnitude of the δ-coefficients in the auxiliary model (5). That is to say, $\text{plim}_{N\to\infty}(\hat{\alpha}_i) = \alpha_{i0} + \delta_i$. Focusing on the bias in the estimated scale elasticity ($\hat{\epsilon} \equiv \sum_i \hat{\alpha}_i$), we have

$$\begin{aligned} \text{plim}_{N\to\infty}\hat{\epsilon} - \epsilon &= \text{plim}_{N\to\infty}\left(\sum_{i=1}^{L}\hat{\alpha}_i\right) - \sum_{i=1}^{L}\alpha_i \\ &= \sum_{i=1}^{L}\delta_i, \end{aligned} \tag{6}$$

where ϵ is the true scale elasticity. The question now is: Will there be a systematic relationship between the changes in the price a firm charges and the growth of the firm in terms of its *inputs*? A satisfactory analysis of the relationship between the price a firm charge and the size of the firm requires a more complete model which includes the factors which determine the firm's price setting behavior and demand. The next section will provide a simple model incorporating these aspects into a complete formal framework. For the moment we will provide a more general, but less formal discussion.

Let us first consider the impact of idiosyncratic changes in (quality adjusted) factor prices. This case is simple, and suggests that firms which experience higher costs will, *ceteris paribus*, charge a higher price and loose market share. Hence, idiosyncratic changes in factor prices suggest a negative relationship between firms' price movements and the changes in input levels, i.e. $\sum_{i=1}^{L}\delta_i < 0$.

The next case to consider is the relationship between price and the level of inputs, when there are idiosyncratic productivity shocks. If efficiency levels differ between firms, it seems plausible that the more productive firm will have a larger market share, and also charge a lower price. If some firms experience productivity improvements beyond the average, they will probably, *ceteris paribus*, obtain a larger market share, measured in terms of (quality adjusted) output. However, more output does not necessarily imply more inputs when productivity improves. For the specific model presented in the next section, it turns out that the two effects - the larger market share versus higher productivity - exactly cancel out so there is no systematic relationship between changes in price and variations in inputs. For that particular model, the larger market share obtained as a result of higher productivity (and there by a lower quality adjusted price) is just offset by the reduction in inputs per unit output, so that the movements in firms' inputs and the changes in output prices are uncorrelated. Beyond that particular model, we are not able to make any general predictions about the relationship between changes in relative prices and the growth of firms measured in terms of inputs, when the differences are due to idiosyncratic productivity movements. Consequently, the bias in the scale estimator related to changes in relative efficiency between firms can in general not be predicted from purely theoretical considerations, even if we are willing to impose "plausible" assumptions.

The last case we want to discuss here is the consequences of demand shocks. If there are scale economies, changes in firm size will affect the price a firm charges in an imperfectly competitive environment. With decreasing returns to scale, we would expect a firm which grows faster than the average, to increase its relative price, and *vice versa.* Hence, this case suggests positive (negative) δ-coefficients in the auxiliary equation (5) if there are negative (positive) scale economies. It follows that demand shocks will bias the estimated scale elasticity towards unity.

2.2 Scale estimates from cost functions

A similar result to the inconsistency pointed out in the production function case applies when estimating cost functions replacing real output with deflated sales. To make this argument as transparent as possible, we will stick to the "linear-in-variables" case[6].

$$c = W\gamma_0 + \beta_0 q + u^c \tag{7}$$

is assumed to be the true relationship. c is a $(N \times 1)$ - vector representing the growth in costs. W is a $(N \times K)$ matrix expressing the growth in the K factor prices for the N observations. q is growth in real output as above. β_0 is the parameter of interest. It is the inverse of the scale elasticity. Once more, we assume that we do not observe real output growth; q. The estimated model assumes the same relationship replacing output with deflated sales:

$$c = W\gamma + \beta r + \tilde{u}^c$$

[6] That is, we consider the cost function corresponding to a Cobb-Douglas production function.

$$= \quad Z\lambda + \tilde{u}^c, \tag{8}$$

where Z denotes the $(N \times (K+1))$ matrix obtained by adding the (column-) vector r to the W-matrix. λ is the $(K+1)$ column vector containing γ and β. It follows that the OLS-estimator of λ, assuming orthogonality of $\tilde{u}^c$, is

$$\hat{\lambda} = (Z'Z)^{-1}Z'c \tag{9}$$

Using the expression $r - q = \pi$, we can rewrite equation (7):

$$\begin{aligned} c &= W\gamma_0 + \beta_0 r + \beta_0(q - r) + u^c \\ &= Z\lambda_0 - \beta_0\pi + u^c, \end{aligned} \tag{10}$$

where λ_0' is the true parameter values (γ_0', β_0). It follows that the probability limit of $\hat{\lambda}$ is given by

$$\text{plim}_{N\to\infty}(\hat{\lambda}) = \lambda_0 - \beta_0 \, \text{plim}_{N\to\infty}(Z'Z)^{-1}Z'\pi + \text{plim}_{N\to\infty}(Z'Z)^{-1}Z'\tilde{u}^c, \tag{11}$$

At this point we again neglect the last term in equation (11). The problem in focus here is the second term on the right hand side of equation (11). Once more we can obtain some intuition about this term by noting that $\text{plim}_{N\to\infty}(Z'Z)^{-1}Z'\pi$ can be thought of as the coefficient associated with the regression of π on Z. That is to say, the term $\text{plim}_{N\to\infty}(Z'Z)^{-1}Z'\pi$ is equal to the $\tilde{\delta}$-vector in the auxiliary regression

$$\begin{aligned} \pi &= Z\tilde{\delta} + v^\pi \\ &= W\tilde{\delta}_W + r\tilde{\delta}_r + v^\pi \end{aligned} \tag{12}$$

where v^π is an orthogonal error term. The question in focus is whether and how the scale coefficient will be biased, which is equivalent asking about the significance and magnitude of the $\tilde{\delta}_r$-coefficient in the OLS-regression of the model in equation (12). Ruling out the unlikely case of inelastic demand, this coefficient will be negative. Notice that if we neglect the last term in equation (11), we have

$$\text{plim}_{N\to\infty}\hat{\beta} = \beta_0(1 - \tilde{\delta}_r) \tag{13}$$

It follows that the cost function estimates of the scale elasticity – equal to the inverse of $\hat{\beta}$ – will be biased downwards in the limit.

In passing, let us notice that the parameters associated with the factor prices will be biased downwards, as the movements in factor prices will tend to be positively correlated with the changes in relative price, π (i.e. $\delta_W > 0$).

3 Bias formulas in an explicit model

In this section we will provide a more formal argument of the inconsistency of the scale estimate in the production function case. This model permits us to formally examine simultanously two sources of bias: (i) The "omitted price bias", discussed in the previous section, and (ii) the bias due to the endogeneity of inputs, i.e. the "transmission bias" (cf. footnote 3). We will augment the production function model in equation (1) with a simple demand equation and a price setting rule. To keep the argument as transparent as possible, we have restricted the analysis to the log-linear case. This restrictive case is sufficient to highlight our main points.

First, consider the production function (cf. equation (1)). Sticking to the one input case[7], we have:

$$Q_{it} = A_{it} X_{it}^{\epsilon}. \tag{14}$$

Q_{it}, A_{it} and X_{it} are the output, productivity and input of firm "i" at time "t". The demand function facing the firm, can be expressed as follows:

$$Q_{it} = D_{it} P_{it}^{\eta}, \tag{15}$$

where D_{it} is a demand shifter. P_{it} is the price relative the general price level in the industry. η is the demand elasticity[8]. The environment we have in mind is an industry with horizontal product differentiation[9]. A finite η corresponds to product differentiation between the goods

[7] Assuming either that there is a Leontief technology, fixed ratios between the factor prices or an appropriate input index has been constructed.

[8] Such a demand system has been widely examined in the industrial organization and international trade literature under the label "the Spence-Dixit-Stiglitz-model". The characteristic feature of this formalization of monopolistic competition is that it leads to price elasticities which are constant and independent of the number of variants available, as expressed in equation (15). Tirole (1988, ch. 7.5) provides a discussion and further references to the micro foundations of this demand system.

[9] Vertical product differentiation is hidden in the possibility that Q_{it} can be an index capturing both the quantity and quality of the output.

produced by the different firms in the industry[10]. If we employ the relationship between true output and deflated sales; $R_{it} = P_{it}Q_{it}$, equation (15) can be rewritten

$$Q_{it} = R_{it}^{\eta/(\eta+1)} D_{it}^{1/(\eta+1)} \tag{16}$$

We will assume that the firms apply a markup rule:

$$\frac{R_{it}}{C_{it}} = \frac{\mu_{it}}{\epsilon} \tag{17}$$

where R_{it} and C_{it} are (deflated) revenues and total (deflated) costs. μ_{it} and ϵ represent the markup and the scale elasticity.

Assuming cost minimization, we have that

$$C_{it} = W_{it}\,(Q_{it}/A_{it})^{1/\epsilon}\,. \tag{18}$$

W_{it} is the deflated factor price. It is convenient to deflate the factor price with the same deflator as we used for the output price (P_{it}). A_{it} is the productivity level as above, while ϵ is the scale elasticity. Inserting equation (17) into equation (18), we get

$$R_{it} = \frac{\mu_{it}}{\epsilon} W_{it}\,(Q_{it}/A_{it})^{1/\epsilon}\,. \tag{19}$$

Taking the logarithmic differences between the time "t" and "t-1" versions of equations (14), (16) and (19), we get the following system of equations:

$$\begin{aligned} q_{it} &= \epsilon\, x_{it} + u_{it}^{q}, \\ q_{it} &= \frac{1}{\eta+1} d_{it} + \frac{\eta}{\eta+1} r_{it}, \\ r_{it} &= w_{it} + (q_{it} - u_{it}^{q})/\epsilon + u_{it}^{m}, \end{aligned} \tag{20}$$

where we use the notation that a lower case letter (e.g. q_{it}), corresponds to the logarithmic differenced upper case variable ($\log(Q_{it}) - \log(Q_{i,t-1})$). The variables u_{it}^{q} and u_{it}^{m} represent $\log(A_{it}) - \log(A_{i,t-1})$ and $\log(\mu_{it}) - \log(\mu_{i,t-1})$. That is, u_{it}^{q} corresponds to productivity shocks, while u_{it}^{m} captures deviations from a fixed markup rule[11]. Notice that the last equation in (20)

[10] For a more elaborate discussion and further references on the econometric modeling of demand in industries with product differentiation, see Berry (1994).

[11] In the case of price setting firms, with a finite number of firms, the deviations from a fixed markup rule will be related to a firm's market share. That is, $u_{it}^{m} \sim$ the deviation in the firm's market share from the mean market

can be simplified by substituting x_{it} for the second term on the right hand side (using the first equation in (20)).

Assuming that the system of equations in (20) describes the economic environment facing our firms, we can examine the bias in the production function estimate of the scale elasticity. The first equation in (20) can be rewritten

$$r_{it} = \epsilon x_{it} + (r_{it} - q_{it}) + u_{it}^q \tag{21}$$

It follows that the probability limit of OLS-estimator of the scale elasticity, based on deflated sales as a proxy for real output, can expressed as

$$\begin{aligned} \text{plim}(\hat{\epsilon}) &= \text{plim}\left[\frac{\sum_{i,t} x_{it} r_{it}}{\sum_{j,s} x_{js}^2}\right] \\ &= \epsilon + \text{plim}\left[\frac{\sum_{i,t} x_{it}(r_{it} - q_{it})}{\sum_{j,s} x_{js}^2}\right] \\ &\quad + \text{plim}\left[\frac{\sum_{i,t} x_{it} u_{it}^q}{\sum_{j,s} x_{js}^2}\right], \end{aligned} \tag{22}$$

where the sums in the numerator and denominator should be carried out over all observations, both across firms and over time. The probability limit is taken with respect to the number of observations[12]. In this expression, let us first focus on the term involving the discrepancy between deflated sales and real output, which we will term *the "omitted price bias"* (since it can be thought of as caused by omitting the individual price from the production function regression). This bias term will be denoted by Δ_1. The last term on the right hand side of equation (22) is the *"transmission" bias*, due to the correlation between the variable input(s) and the productivity shock. This term will be denoted by Δ_2.

Solving the system of equations in (20) with respect to x_{it} and $(r_{it} - q_{it})$, in terms of the supply shocks (w_{it}, u_{it}^q and u_{it}^m) and the demand shock (d_{it}), we find that

share, see Klette (1990, ch. 4). In the case of vertical product differentiation, the markups might be correlated with the quality of the firms' output. See Tirole (1988, ch. 7.5.1) for discussion and references. One can argue that u_{it}^m will develop in the time dimension depending on the firm's innovative history. E.g. an idiosyncratic productivity shock might lead the innovative firm to charge a higher markup, as discussed by Arrow (1962) in the competitive case and by Kamien and Schwartz (1982) in the oligopolistic case. The pattern of variations in u_{it}^m will be more complex if the firm takes into consideration intertemporal dependence in demand or production economies (cf. Tirole, 1988, ch. 1.1.2). Finally, notice that u_{it}^m also will capture deviations from a common scale elasticity across firms and over time. To keep our problem tractable, we will assume that u_{it}^m fulfills some suitable orthogonality conditions.

[12] In practice, we might want to allow for a non-trivial time structure of the productivity shocks, by e.g. incorporating time dummies into the equation. In that case, the relevant limit to consider is with respect to an increasing number of firms.

$$r_{it} - q_{it} = \frac{1}{\epsilon(\eta+1)-\eta}\left[\epsilon(w_{it} + u^m_{it}) + (1-\epsilon)d_{it} - u^q_{it}\right], \tag{23}$$

and

$$x_{it} = \frac{1}{\epsilon(\eta+1)-\eta}\left[d_{it} - (\eta+1)u^q_{it} + \eta(w_{it} + u^m_{it})\right]. \tag{24}$$

Using equations (23) and (24) the "the omitted price bias" bias can be expressed

$$\begin{aligned}
\Delta_1 &\equiv \text{plim}\left[\frac{\sum_{i,t} x_{it}(r_{it} - q_{it})}{\sum_{j,s} x^2_{js}}\right] \\
&= \left\{\text{plim}\frac{1}{N}\sum_{i,t}\left[d_{it} - (\eta+1)u^q_{it} + \eta(w_{it} + u^m_{it})\right]\right. \\
&\qquad \left. \times \left[\epsilon(w_{it} + u^m_{it}) + (1-\epsilon)d_{it} - u^q_{it}\right]\right\} \\
&\quad \times \left\{\text{plim}\frac{1}{N}\sum_{j,s}\left[d_{js} - (\eta+1)u^q_{js} + \eta(w_{js} + u^m_{js})\right]^2\right\}^{-1}.
\end{aligned} \tag{25}$$

N is the number of observations. To obtain some intuition about this expression, let us assume that all the factor price, productivity, price setting and demand shocks are orthogonal. Then the "omitted price bias" can be expressed in terms of the variances:

$$\Delta_1 = \frac{\epsilon\eta(\sigma^2_w + \sigma^2_m) + (\eta+1)\sigma^2_q + (1-\epsilon)\sigma^2_d}{\eta^2(\sigma^2_w + \sigma^2_m) + (\eta+1)^2\sigma^2_q + \sigma^2_d}. \tag{26}$$

$\sigma^2_w, \sigma^2_m, \sigma^2_q$ and σ^2_d are the variances of the factor prices, the "markup-disturbance" (u^m), the productivity shocks and demand shocks.

Notice first that as the elasticity of substitution (represented by $-\eta$) between the differentiated goods in the industry tends to infinity, the bias from neglecting the price differences will vanish. This situation corresponds to the standard case with no product differentiation. The important point is that if there is no horizontal product differentiation in the industry, there is no scope for differences in *quality adjusted* prices. In this case, differences in sales corresponds to differences in inputs (costs), so sales is a valid measure for quality adjusted output[13]. This is essentially a perfectly competitive situation.

[13]This argument has been used to justify quality adjustment of an input price on the basis of changes in the cost of producing the input. See the discussion between Gordon and Triplett in Foss (1982, ch. 4 and 5).

Equation (26) shows that if the demand shocks dominate, the bias will be $1 - \epsilon$. That is to say, pure demand shifts will bias the scale estimate towards unity. Below, we will show that this results holds more generally when we take into consideration that productivity shocks are "transmitted" to inputs.

Only if there are both decreasing returns to scale *and* the demand shocks dominate will there be an upward bias in the scale estimate. If there are increasing returns to scale, demand shocks will also contribute to a downward bias in the scale elasticity. Presence of the various supply shocks will all tend to bias the scale elasticity downwards. Notice that with a fairly high elasticity of substitution between the goods in the industry, or a scale elasticity close to unity, the magnitude of the inconsistency due to demand shocks will tend to be dwarfed by the supply shocks.

Let us now incorporate the "transmission bias" (Δ_2) into the analysis. Assuming orthogonality between the various shocks, it follows by using equation (24), that

$$\begin{aligned}\Delta_2 &\equiv \text{plim}\left[\frac{\sum_{it} x_{it}u^q_{it}}{\sum_{ls} x^2_{ls}}\right] \\ &= -\frac{(\eta+1)[\epsilon(\eta+1)-\eta]\sigma^2_q}{\eta^2(\sigma^2_w+\sigma^2_m)+(\eta+1)^2\sigma^2_q+\sigma^2_d}. \qquad (27)\end{aligned}$$

This expression has an interesting implication. Consider the case of perfect competition (i.e. $\eta \to -\infty$). Recall that Δ_1 is zero in this case. Inserting equation (27) into (22), and let $\eta \to -\infty$ we find that

$$\text{plim}(\hat{\epsilon}) = \frac{1}{1+\theta} + \frac{\theta}{1+\theta}\epsilon, \qquad (28)$$

where θ is the ratio $(\sigma^2_w + \sigma^2_m)/\sigma^2_q$. That is, the ordinary production function regression provides a scale estimate with a probability limit which converges to a weighted average of unity and the true scale coefficient, as demand gets infinitely elastic.

More generally, we find that

$$\begin{aligned}\text{plim}(\hat{\epsilon}) &= \epsilon + \frac{\epsilon\eta(\sigma^2_w+\sigma^2_m)+(\eta+1)^2(1-\epsilon)\sigma^2_q+(1-\epsilon)\sigma^2_d}{\eta^2(\sigma^2_w+\sigma^2_m)+(\eta+1)^2\sigma^2_q+\sigma^2_d} \\ &= 1+\eta(\epsilon+\eta(\epsilon-1))\frac{\sigma^2_w+\sigma^2_m}{\eta^2(\sigma^2_w+\sigma^2_m)+(\eta+1)^2\sigma^2_q+\sigma^2_d}. \qquad (29)\end{aligned}$$

This expression shows that if the cross sectional differences in factor price shocks and changes in price cost margins are negligible relative to the differences in demand and productivity shocks, the scale estimator $\hat{\epsilon}$ will have a probability limit equal to unity, whatever is the value of the true scale elasticity! More generally, if $(\epsilon + \eta(\epsilon - 1)) > 0$ the probability limit is below unity.

An interesting extension of the preceding analysis is to consider the case where u_{it}^m and u_{it}^q are correlated. What we have in mind, is that a firm which experiences a positive productivity shock might not fully pass it over to consumers by lowering its price[14]. This corresponds to a positive correlation between u_{it}^m and u_{it}^q. When $u_{it}^m = u_{it}^q/\epsilon$, a productivity shock is fully offset by a change in the markup, as can be seen from equation (20). The consequence of allowing for a non-zero correlation between the productivity and the markup shocks, is to add a new term $-(\eta\epsilon + \epsilon)\ \mathrm{Cov}(u_{it}^m, u_{it}^q)$ to the numerator of the bias term in equation (29) (cf. the expression on the right hand side in the first line of equation (29)). An additional term will also appear in the denominator in the bias term in equation (29), equal to $-2\eta(\eta + 1)\ \mathrm{Cov}(u_{it}^m, u_{it}^q)$. If there is a positive correlation between u_{it}^m and u_{it}^q, the additional term in the numerator is positive. The new term in the denominator is negative. Consequently, a positive correlation between productivity movements and markup changes will pull the total bias in an upward direction.

4 Towards consistent estimates of the scale elasticity

In this section we illustrate some of the theoretical issues outlined above in the context of an actual study of firm data. This study presents one tentative approach to the estimation of the scale elasticity from regressions based on deflated sales, given that real output is not observable. It makes two major points: The first is that the parameters in the augmented production function regressions will be reduced form parameters, which are mixtures of supply and demand parameters. Second, we argue that by adding deflated sales to the production function and factor demand models, we can identify the structural parameters of interest.

4.1 Common estimating equations

We start by explicitly stating the estimating equations considered in our empirical analysis. The models considered are the Cobb-Douglas production function and a cost function. We have also estimated a semi-parametric version of a model presented by Hall (1990). All these estimated

[14]Cf. the discussion in footnote 11.

models provide inconsistent estimates of the scale elasticity when deflated sales are used to replace output, as discussed above.

The estimating equation for the (Cobb-Douglas) production function is

$$q_{it} = \beta_1^q(m_{it} - l_{it}) + \beta_2^q(e_{it} - l_{it}) + \beta_3^q l_{it} + \beta_4^q k_{it} + u_{it}^q. \tag{30}$$

The variables m_{it}, l_{it}, e_{it} and k_{it} refer to materials, labour, energy and capital. Let us emphasize that the transformation of the variables in equation (30) imply that β_3^q corresponds to the scale elasticity of all the variable factors (labour, energy and materials).

The next case we consider is the factor demand function, derived from a "restricted cost function" with predetermined capital. The estimating equation in this case is

$$x_{it} = \beta_1^x q_{it} + \beta_2^x k_{it} + u_{it}^x. \tag{31}$$

The dependent variable in this equation is an (cost weighted) index of variable inputs:

$$x_{it} \equiv \sum_{j\in\{L,M,E\}} s_{it}^j x_{it}^j, \tag{32}$$

where s_{it}^j is the cost share of factor j[15]. The inverse of β_1^x in equation (31) is the scale elasticity of variable inputs.

We have also considered a model which relates the growth in output to the cost-weighted input measure, growth in capital inputs and a residual[16]:

$$q_{it} = \tilde{\beta}_1^q x_{it} + \tilde{\beta}_2^q k_{it} + \tilde{u}_{it}^q. \tag{33}$$

As stated by Hall (1990), the $\tilde{\beta}_1^q$ parameter can be interpreted as a scale parameter. That is to say, the specification in equation (33) implies that the $\tilde{\beta}_1^q$ parameter can be interpreted as the scale parameter of *variable inputs.* Models (31) and (33) are equivalent except, possibly, with respect to stochastic assumptions.

[15] Alternatively, we could have estimated (a system of) restricted factor demand functions for each of the variable inputs. The approach taken here highlights the similarity, as well as the difference in terms of stochastic specification, between the production function and the factor demand approach to production econometrics.

[16] This is a slight modification - using gross output rather than value added - to a model considered by Hall (1990). Notice that equation (30) is equal to equation (33) if we replace $\tilde{\beta}_1^q x_{it}$ by $\beta_1^q(m_{it}-l_{it})+\beta_2^q(e_{it}-l_{it})+\beta_3^q l_{it}$ in the latter equation.

One set of our estimates follow common practice and use deflated sales (r_{it}) as our proxy for real output (q_{it}). This procedure creates the omitted variable bias associated with the discrepancy between the growth in the individual price relative to the applied deflator, as spelled out in sections 2 and 3. In the next section we will show that after adding an extra variable - growth in industry sales - to equations (30), (31) and (33), we can reinterpret the parameters, and identify the scale elasticity and other parameters of interest.

4.2 Reduced form models

In the model presented in section 3, we were able to express output in terms of deflated sales (cf. equation (20)). We will apply essentially the same approach here in the empirical model. But let us generalize the demand system somewhat: $Q_{it} = D_{It}(P_{it}/P_{It})^{\eta} P_{It}^{\nu} e^{u_{it}^{d}}$. That is to say, demand is determined by a component which varies over time but is common across firms within an industry (D_{It} ; 'I' refers to the industry to which firm 'i' belongs), substitution effects across products within the industry ($(P_{it}/P_{It})^{\eta}$), substitution effects to outside goods (P_{It}^{ν}) and an idiosyncratic part (u_{it}^{d}). P_{it} is here the firm specific price, while P_{It} is the average price in the industry. The demand system in growth terms can be written

$$q_{it} = d_{It} + \eta(p_{it} - p_{It}) + \nu p_{It} + u_{it}^{d}. \tag{34}$$

Using $r_{it} = q_{it} + p_{it} - p_{It}$, it follows that

$$q_{it} = \frac{\eta}{\eta+1} r_{it} + \frac{1}{\eta+1}(d_{It} + \nu p_{It} + u_{it}^{d}). \tag{35}$$

Combining this equation and equation (30), we get

$$r_{it} = \frac{\eta+1}{\eta}[\beta_1^q(m_{it} - l_{it}) + \beta_2^q(e_{it} - l_{it}) + \beta_3^q l_{it} + \beta_4^q k_{it}] - \frac{1}{\eta}[d_{It} + \nu p_{It}] + v_{it}^{q}. \tag{36}$$

v_{it}^{q} is a composite mean-zero error term. Similarly for the factor demand specification. By combining equations (31) and (35), we get

$$x_{it} = \frac{\eta\beta_1^x}{\eta+1} r_{it} + \beta_2^x k_{it} + \frac{\beta_1^x}{\eta+1}[d_{It} + \nu p_{It}] + v_{it}^{x}. \tag{37}$$

Lastly, combining equations (33) and (35):

$$r_{it} = \frac{\eta+1}{\eta}\left(\tilde{\beta}_1^q x_{it} + \tilde{\beta}_2^q k_{it}\right) - \frac{1}{\eta}[d_{It} + \nu p_{It}] + \tilde{v}_{it}^q. \tag{38}$$

Notice that in the models presented in equations (36) – (38) both the η- and the production/cost function parameters of interest are identified. However, we can not identify the the price elasticity which captures substitution effect to outside goods (the ν-parameter), without access to d_{It} and p_{It} as separate variables, which we do not have (see below).

Let us add some intuition on why the models (36) – (38) are identified, when aggregate demand changes are added to usual production variables: In an imperfectly competitive industry, there is a convex relationship between the (deflated) sales of a firm and its real output, when the firm grows by undercutting the price of its competitors. (The convexity is determined by the factor $(\eta+1)/\eta$.) This (extra source of) convexity is not present when the firm grows due to aggregate demand changes, either trough a shift in the demand schedule (cf. d_{It}) or through a price decline common across the firms in the industry (cf. νp_{It}). Hence, growth in revenue will exceed growth in inputs by a larger margin in a less competitive industry, when there are changes in aggregate demand.

4.3 The data sources and variable construction

The data source used in this analysis is the annual census carried out by Statistics Norway. Aggregate numbers and definitions for the census are reported in NOS (several years. See also Halvorsen et al. (1991)). We have employed an unbalanced sample of annual observations for the period 1983-89 (inclusive) for 4 industry groups producing "Metal products, machinery and equipment". The sample includes only establishments with at least 5 employees. Plants with incomplete reports for the variables needed in the estimation have been eliminated, but no other cleaning has been carried out. Summary statistics for the employed sample are reported in table 1.

All variables are expressed in terms of growth rates (more precisely; in first differences of logarithms of the variables). In all models, we have applied a Tornquist index for the variable inputs, i.e. the shares are constructed as the average share for the two years used to construct the growth rates. The output measure is gross output adjusted for duties and subsidies. Labour inputs are represented by man hours. Price deflators for gross production (at seller prices), materials, energy and capital (at buyer prices) are taken from the Norwegian National Accounts.

Wage payments comprise salaries and wages in cash and kind, other benefits for the employees, taxes and social expenses levied by law.

The capital input variable employed is based on investment figures and the total reported fire insurance value for buildings and machinery. The annual movements are obtained by assuming geometric depreciation at a 3 percent annual rate, and that investment takes about a year to become productive[17]. This last assumption is imposed also to reduce biases caused by the possibility that investments respond to contemporaneous productivity shocks.

We have used the (weighted) average growth in deflated sales across all firms in each (5-digit) industry, as our proxy for the aggregate shock term, $[d_{It} + \nu p_{It}]$, in eqs. (36)-(38). In the appendix, we have shown that this is a valid procedure when the growth rate in the aggregate output deflator is a (weighted) average of the (unobserved) growth rates in the individual output prices.

4.4 Other econometric issues

For both the factor demand models (cf. equations (31) and (37)) and the semi-parametric models (cf. equations (33) and (38)), we have both carried out OLS and instrumental variable regressions. Changes in the number of employees is used as an instrumental variable[18]. The motivation for using an IV-approach is twofold: First, it seems likely that the number of employees is less responsive to short term changes in productivity, as compared to manhours, materials and energy in the production function and semi parametric models. Similarly, in the factor demand model we believe that the number of employees is less affected by temporary shifts in productivity relative to deflated sales. If these claims are true, the orthogonality assumption with the error term is a better approximation when using changes in employees as an instrument. Notice that permanent differences in productivity between firms will not cause any simultaneity bias, as all variables are expressed in terms of (annual) growth rates[19].

[17]An examination of the fire insurance values and a comparison with the investment figures reveal much noise in the fire insurance values. We have constructed a simple filter to pool the two sources of information about movements in the capital stock. Essentially the filter identifies the level of the capital stocks from the fire insurance values. Extreme fire insurance values have been eliminated.

[18]We could also have used lagged variables as instruments, as suggested by one referee. This approach has been extensively explored in Klette (1994). The problem with this approach is that there is little identifying power in past changes for current changes. And as is well known, with weak instruments the IV-estimator is very vulnerable to even weak correlation between the error term and the instruments.

[19]Furthermore, productivity movements which are not predictable before the input quantities are chosen, will not cause any bias. Cf. Zellner et al. (1966).

Second, any measurement errors in the input index will cause a bias in the OLS regression. Measurement errors might be introduced if we are using weights which randomly deviate from the correct shares when constructing the input index, as well as for a variety of other reasons. If these measurement errors are uncorrelated with changes in employment, using the IV-approach will remove the bias due to errors of measurement in the input variables.

4.5 The empirical results

Table 2 reports the results obtained from estimating the production function in equation (30), as well as a model where the production function is augmented by adding the constructed aggregate demand change variable as an explanatory variable. The main result to notice is that the aggregate demand change variable is highly significant. However, rather than elaborating on these estimates, we will notice that the semi parametric model spelled out in equation (33) performs uniformly better in terms of the RMSE[20]; see tables 3 – 6. Also, the scale estimates obtained by the semi parametric model are likely to be more consistent, as we are able to instrument the variable inputs (manhours, energy, materials) which are liable to be correlated with high frequency movements in productivity buried in the residual. In what follows we will focus on the semi parametric model, instead of the standard production function model.

Tables 3-6 summarize the main results for each industry group separately. The first two columns in each of the four tables, refer to estimation of the semi parametric model in equation (33). Columns 3 and 4 present results obtained from the factor demand model (cf. equation (31)), which is essentially the same regression but with a reshuffling of the left hand side and right hand side variables. The last two columns provide results from estimated models augmented by including the aggregate demand change variable in the regression.

One should notice that the reported RMSE-values refer to the root mean square prediction error of deflated sales, rather than the prediction error of the different dependent variables. This is done in order to facilitate comparisons between the various (non-nested) models.

The first column in table 3 gives an estimate around 0.91 (standard error equal to 0.007) of what is traditionally interpreted as the scale elasticity of the variable inputs. The estimated constant term suggests an average productivity decline around -1 percent per year (same as the

[20] Notice that the two models (equations (30) and (33)) are not nested, so traditional testing procedures are not appropriate.

reported TFP-figure in table 1).

The estimated coefficient for capital growth has the wrong sign, but is not significant. The insignificance of capital is a result which persists throughout our estimations. Our belief is that with the available quality of our capital measures, it is not possible to trace the annual changes in capital services. We will add further comments on this problem in the final section of the paper.

As we compare the results from the various models, only one of the estimated scale parameters deviates significantly from the results just reported. That is the scale estimate obtained by OLS estimation of the factor demand model. The scale estimate is 1.13 (=1/0.883), and it is very precisely estimated. However, when we instrument growth in deflated sales by the growth in number of employees, the estimated scale coefficient declines to 0.93 (same as the result obtained in column 2, as we would expect, since the results reported in column 2 is obtained using the same instruments and the rest of the model is essentially the same). There are two reasons why we will place greater trust in the (higher) IV-estimate of the sales coefficient. First, random measurement errors in deflated sales will cause a downward bias in the estimated sales coefficient (and thereby an upward bias in the scale elasticity) [21]. Second, a similar bias will arise due to the (negative) correlation between sales and the cost function error term, which incorporates the productivity movements with a negative sign. As discussed above, our instrument is likely to remove at least some of these biases.

Before we continue the discussion of the scale estimates, notice that the aggregate demand change variable is highly significant when introduced into the regressions, suggesting that the firms do not face perfectly elastic demand curves (cf. columns 5 and 6). Using equations (37) and (38), we can identify the demand elasticity from column 5 and 6 in table 3. Simple calculations show that the two models implies a demand elasticity around -6.2. We can also identify the scale elasticity from the two set of estimates, which turn out to be about 1.10 in both cases. The same calculations for the other industries are reported in table 6.

The results for the other industries are very similar to the findings discussed above. In particular we find that after taking into consideration the demand equation facing the firms, the results are almost identical across the two estimated models. The findings are also quite

[21]This bias was pointed out by Friedman (1955), and was labeled the "regression fallacy". Friedman's discussion was one of the first examinations of the consequences of random measurement errors in the regressors, in an econometric context.

similar across industries. Our results suggest significant, but not very large, scale economies in all industries. The results also suggest that the firms face a less than perfectly elastic demand curve, with a demand elasticity around - 6 to - 12.

5 Additional remarks

This paper has identified some problems of interpretation of the production function parameters when deflated sales is used instead of real output as the dependent variable. The problems arise in situations where the firms compete in an environment with differentiated products and imperfect competition, where prices will reflect idiosyncratic differences in cost. The basic insight is that a firm experiencing a cost improvement beyond the industry average, will be inclined to undercut its competitors price and thereby expand its market share. However, since the firm will have a below average change in price, the expansion in sales will be less than proportional to the growth in output. It follows that replacing changes in real output by growth in deflated sales will introduce a bias in the standard approaches to estimation of production parameters. The main contribution of this paper is to present an analysis of the nature and consequences of this bias for widely applied estimators of scale economies.

Our paper also provides some empirical results from a production function and factor demand models, augmented by incorporating average, industry wide sales into the estimating equation. By adding this variable capturing aggregate demand changes, we show that scale economies and price cost ratios are identifiable from the augmented estimating equations. Notice that the aggregate demand changes can be caused by both aggregate demand and supply shocks, without altering the interpretation of our parameters. Different specifications of the production model are examined. Our findings suggest that the firms in the industries we examine face downward sloping demand curves with significant, but moderate price elasticities. The results also reveal some scale economies.

One problem with our findings is the non-significance of capital in our empirical models. As the equations are in first differences, this result is consistent with the general experience with these kind of data. The usual explanation is simple: The quality of our capital measures is too poor to identify the annual variations in capital services. Two key problems in this respect are variations in capacity utilization and investment lags. These issues raises the question of how we should incorporate capital into our models. Does capital have a positive (shadow) price only when the firm operates at full capacity? And closely related; how does the firm incorporate the shadow price of capital into its pricing decisions? We believe that a more satisfactory solution to these questions requires an explicit dynamic model of investment behavior, incorporating uncertainty[22]. In our estimates, we suspect that changes in the capital services are picked up by movements in the variable inputs (particularly energy) in our production function regressions, and by the deflated sales variable in the cost function regressions.

[22] See Eden and Griliches (1993) for an analysis of some of the issues which arise in a dynamic setting which emphasizes the importance of capacity choice and uncertainty.

References:

Abbott, T.A., Z. Griliches and J.A.Hausman (1988): Short Run Movements in Productivity: Market Power versus Capacity Utilization. Unpublished paper.

Arrow, K.J. (1962): Economic Welfare and the Allocation of Resources for Invention, in *The rate and direction of inventive activity* by R.R. Nelson (ed.), Princeton University Press.

Bartelsman, E.J., R.J. Caballero and R.K. Lyons (1991): Short and Long Run Externalities. NBER Working Paper No. 3810

Berry, S.T. (1994): Estimating Discrete-Choice Models of Product Differentiation, *Rand Journal of Economics* 25, 242-62.

Cuneo, P. and J. Mairesse (1984): Productivity and R&D at the Firm Level in French Manufacturing, in *R&D, Patents and Productivity*, by Z. Griliches (ed.), University of Chicago Press.

Dunne, T. and M.J. Roberts (1992): Costs, Demand, and Imperfect Competition as Determinants of Plant-Level Output Prices. Discussion Paper CES 92-5, Center for Economic Studies, U.S. Bureau of the Census.

Eden, B. and Z. Griliches (1993): Productivity, Market Power and Capacity Utilization when Spot Markets Are Complete. *American Economic Review, Papers and Proceedings*, 83, 219-23.

Friedman, M. (1955): Comment on "Survey of the Empirical Evidence on Economies of Scale" by C.A. Smith, in *Business Concentration and Price Policy, A Report of the National Bureau of Economic Research*, Princeton University Press (Princeton).

Foss, M.F. (1982): *The U.S. National Income and Product Accounts.* University of Chicago Press.

Griliches, Z. (1957): Specification Bias in Estimates of Production Functions, *Journal of Farm Economics* 39, 8-20.

Griliches, Z. and J.A.Hausman (1986): Errors in Variables in Panel Data, *Journal of Econometrics* 18, 93-118.

Griliches, Z. and J. Mairesse (1984): Productivity and R&D at the Firm Level, in *R&D, Patents and Productivity*, Z. Griliches (ed.), National Bureau of Economic Research.

Griliches, Z. and J. Mairesse (1990): Heterogeneity in Panel Data: Are There Stable Production Functions? in P. Champsaur et al. (eds.): *Essays in Honour of Edmond Malinvaud, Vol. 3: Empirical Economics*, MIT Press (Cambridge).

Griliches, Z. and V. Ringstad (1971): *Economies of Scale and the Form of the Production Function*, North-Holland Publ.Co. (Amsterdam).

Hall, R.E. (1990): Invariance Properties of Solow's Productivity Residual, in P. Diamond (ed): *Growth, Productivity, Unemployment*, MIT Press (Cambridge).

Halvorsen, R., R. Jensen and F.Foyn (1991): Dokumentasjon av Industristatistikkens Tidsseriebase ("Documentation of the Panel Data Base for Manufacturing"), Mimeo, Statistics Norway (In Norwegian).

Kamien, M.I. and N.L. Schwartz (1982): *Market Structure and Innovation*, Cambridge University Press (Cambridge).

Klette, T.J. (1990): *Four Essays on Industrial Policy under Imperfect Competition*. Økonomiske Doktoravhandlinger nr. 6, Department of Economics, University of Oslo.

Klette, T.J. (1994): Estimating Price-Cost Margins and Scale Economies from Paneldata, Discussion Paper, Statistics Norway.

Mairesse, J. (1990): Time-Series and Cross-Sectional Estimates on Panel Data: Why Are They Different and Why Should They Be Equal? in J.Hartog, G.Ridder and J.Theeuwes (eds.): *Panel Data and Labour Market Studies*, North Holland Publ. Co. (Amsterdam).

Marschak, J. and W. Andrews (1944): Random Simultaneous Equations and the Theory of Production, *Econometrica* 12, 143-205.

Mundlak, Y. (1978): On the Pooling of Time-Series and Cross-Section Data, *Econometrica* 46, 49-85.

Mundlak, Y. and I. Hoch (1965): Consequences of Alternative Specifications of Cobb-Douglas Production Functions, *Econometrica* 33, 814-28.

Ringstad, V. (1971): *Estimating Production Functions and Technical Change from Micro Data*, Social and Economic Studies 21, Statistics Norway (Oslo).

Ringstad, V. (1974): Some Empirical Evidence on the Decreasing Scale Elasticity, *Econometrica* 42, 87-101.

Tirole, J. (1988): *The Theory of Industrial Organization*, MIT Press (Cambridge).

Zellner, A., J.Kmenta and J.Dreze (1966): Specification and Estimation of Cobb-Douglas Production Functions, *Econometrica* 34, 784-95.

Appendix

In this appendix we show that if the growth rate of the industry wide price deflator is a (weighted) average of the changes in the firm specific prices, the variable capturing aggregate demand changes (cf. $[d_{It} + \nu p_{It}]$) in eqs. (36) - (38), can be constructed as the (weighted) average of the growth in sales for the firms in the industry.

Using the relationship $r_{it} = q_{it} + p_{it} - p_{It}$ and equation (34), we have that

$$r_{it} = d_{It} + (\eta + 1)p_{it} + (\nu - \eta - 1)p_{It} + u_{it}^{d}, \tag{39}$$

where p_{it} and p_{It} are the growth in the price of firm 'i' and industry 'I', respectively, between 't' and 't-1'. Assuming we have weights (w_{it}) such that $\sum_{i \in I} w_{it} p_{it} = p_{It}$ (and $\sum_{i \in I} w_{it} u_{it}^{d} = 0$), it follows that

$$\begin{aligned} \sum_{i \in I} w_{it} r_{it} &= \sum_{i \in I} w_{it}[d_{It} + (\eta + 1)p_{it} + (\nu - \eta - 1)p_{It} + u_{it}^{d}] \\ &= d_{It} + \nu p_{It}, \end{aligned} \tag{40}$$

Hence with the appropriate weights, the aggregate demand change variable, $[d_{It} + \nu p_{It}]$, can be constructed from the weighted average growth in deflated sales.

Table 1: Summary statistics for the four industry groups in the applied sample. Period 1983-89.

Industry	381		382		383		384	
Variable	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.
# Obs.	3966		2560		1182		2454	
Output (*)	0.005	0.326	0.015	0.363	0.013	0.340	-0.001	0.393
TFP (*)	-0.010	0.149	0.004	0.180	-0.003	0.142	0.003	0.218
Labour (*)	-0.004	0.316	-0.009	0.331	0.004	0.271	-0.010	0.365
Capital (*)	0.036	0.351	0.023	0.296	0.038	0.182	0.016	0.138
Dmd.change(*)	-0.001	0.088	0.034	0.103	-0.005	0.140	0.016	0.104
Revenue/var.cost	1.124	0.142	1.102	0.173	1.104	0.135	1.092	0.115
Labour shr. (**)	0.431	0.141	0.441	0.165	0.393	0.131	0.387	0.165
Energy shr.(**)	0.025	0.022	0.019	0.018	0.013	0.011	0.019	0.017
#Empl.	30.8	50.4	73.4	195.0	76.0	175.0	58.5	109.9

Note: Variables indicated by (*) refer to annual growth rates. The cost shares for energy and labour, indicated by (**), refer to shares in variable costs.
Industry 381: Manufacture of metal products, except machinery and equipment
Industry 382: Manufacture of machinery
Industry 383: Manufacture of electrical apparatus and supplies
Industry 384: Manufacture of transport equipment

Table 2: Production function estimates with and without demand shock variable (average deflated sales) included in the regression. Cf. equations (30) and (36). All industries.

INDUSTRY	381		382		383		384	
Labour	0.854 (.009)	0.843 (.009)	0.814 (.014)	0.800 (.014)	0.934 (.018)	0.925 (.018)	0.845 (.011)	0.838 (.011)
Materials per unit of labour	0.470 (.006)	0.465 (.006)	0.400 (.008)	0.394 (.008)	0.502 (.012)	0.500 (.012)	0.554 (.007)	0.550 (.007)
Energy per unit of labour	0.060 (.005)	0.056 (.005)	0.070 (.009)	0.065 (.009)	0.024 (.011)	0.021 (.011)	0.085 (.008)	0.083 (.008)
Capital	-0.005 (.005)	-0.004 (.005)	-0.013 (.008)	-0.011 (.008)	-0.022 (.022)	-0.020 (.022)	0.004 (.004)	0.004 (.003)
Demand shock		0.233 (.030)		0.282 (.040)		0.112 (.034)		0.172 (.035)
Intercept	-0.009 (.003)	-0.009 (.003)	0.007 (.004)	-0.003 (.004)	-0.002 (.005)	-0.002 (.005)	-0.002 (.004)	-0.005 (.004)
R^2	0.75	0.75	0.68	0.69	0.78	0.78	0.80	0.80
RMSE	0.163	0.162	0.206	0.204	0.161	0.160	0.178	0.177

Note: Standard errors in parentheses.
Industry 381: Manufacture of metal products, except machinery and equipment
Industry 382: Manufacture of machinery
Industry 383: Manufacture of electrical apparatus and supplies
Industry 384: Manufacture of transport equipment

Table 3: Estimation results for the models in equations (31), (33), (37) and (38).
Industry 381: Manufacture of metal products, except machinery and equipment.

Model:	BASIC MODELS:				AUGMENTED MODELS:	
Equation:	Semi.param. (33)		Cost fct. (31)		Semi.p. (38)	Cost f. (37)
Estimation method:	OLS	IV	OLS	IV	IV	IV
Variable inputs	0.907 (.007)	0.930 (.010)			0.923 (.010)	
Deflated sales			0.883 (.007)	1.075 (.012)		1.083 (.012)
Capital	-0.005 (.004)	-0.005 (.004)	0.007 (.004)	0.006 (.005)	-0.005 (.004)	0.005 (.005)
Demand shock					0.161 (.027)	-0.174 (.030)
Intercept	-0.007 (.002)	-0.007 (.002)	0.008 (.002)	0.007 (.002)	-0.007 (.002)	0.007 (.003)
RMSE	0.146	0.146	0.163	0.146	0.145	0.145

Note: Numbers in parentheses are standard errors. RMSE refers the root mean square prediction error of deflated sales as implied by the model.

Table 4: Estimation results for the models in equations (31), (33), (37) and (38). Industry 382: Manufacture of machinery

Model:	BASIC MODELS:				AUGMENTED MODELS:	
Equation:	Semi.param. (33)		Cost fct. (31)		Semi.p. (38)	Cost f. (37)
Estimation method:	OLS	IV	OLS	IV	IV	IV
Variable inputs	0.865 (.010)	0.912 (.015)			0.905 (.015)	
Deflated sales			0.871 (.010)	1.096 (.018)		1.105 (.019)
Capital	-0.007 (.007)	-0.006 (.007)	0.003 (.007)	0.007 (.007)	-0.005 (.007)	0.006 (.007)
Demand shock					0.167 (.036)	-0.185 (.041)
Intercept	0.005 (.004)	0.005 (.004)	-0.002 (.004)	-0.005 (.004)	-0.005 (.007)	0.001 (.004)
RMSE	0.180	0.181	0.207	0.181	0.180	0.180

Note: Numbers in parentheses are standard errors. RMSE refers the root mean square prediction error of deflated sales as implied by the model.

Table 5: Estimation results for the models in equations (31), (33), (37) and (38). Industry 383: Manufacture of electrical apparatus and supplies

Model:	BASIC MODELS:				AUGMENTED MODELS:	
Equation:	Semi.param. (33)		Cost fct. (31)		Semi.p. (38)	Cost f. (37)
Estimation method:	OLS	IV	OLS	IV	IV	IV
Variable inputs	0.957 (.013)	0.989 (.019)			0.981 (.019)	
Deflated sales			0.850 (.012)	1.011 (.020)		1.020 (.020)
Capital	-0.023 (.020)	-0.022 (.020)	0.015 (.019)	0.023 (.020)	-0.021 (.020)	0.021 (.020)
Demand shock					0.084 (.031)	-0.085 (.032)
Intercept	-0.002 (.004)	-0.003 (.004)	0.005 (.004)	0.003 (.004)	-0.002 (.004)	0.002 (.004)
RMSE	0.147	0.148	0.163	0.148	0.147	0.147

Note: Numbers in parentheses are standard errors. RMSE refers the root mean square prediction error of deflated sales as implied by the model.

Table 6: Estimation results for the models in equations (31), (33), (37) and (38). Industry 384: Manufacture of transport equipment

Model:	BASIC MODELS:				AUGMENTED MODELS:	
Equation:	Semi.param. (33)		Cost fct. (31)		Semi.p. (38)	Cost f. (37)
Estimation method:	OLS	IV	OLS	IV	IV	IV
Variable inputs	0.913 (.009)	0.919 (.013)			0.912 (.013)	
Deflated sales			0.903 (.008)	1.088 (.015)		1.096 (.016)
Capital	0.005 (.003)	0.005 (.003)	-0.005 (.003)	-0.005 (.004)	0.005 (.003)	-0.006 (.003)
Demand shock					0.139 (.032)	-0.152 (.036)
Intercept	0.001 (.003)	0.001 (.003)	-0.002 (.003)	-0.002 (.004)	-0.001 (.003)	0.001 (.004)
RMSE	0.165	0.165	0.182	0.165	0.164	0.164

Note: Numbers in parentheses are standard errors. RMSE refers the root mean square prediction error of deflated sales as implied by the model.

Table 7: Point estimates of the demand and scale elasticities as implied by the results in table 3-6, columns 5 and 6.

Model:	Semi parametric model		Factor demand model	
Industry	Demand	Scale	Demand	Scale
381	-6.2	1.10	-6.2	1.10
382	-6.0	1.09	-6.0	1.09
383	-11.9	1.07	-12.0	1.07
384	-7.2	1.06	-7.2	1.06

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