A simple method to control for heterogeneous price setting and market power of firms in productivity estimates

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Abstract

The objective of this paper is to derive a method to control for idiosyncratic and unobserved pricing which can easily be used in applied productivity research. Irrespective the empirical focus, the analysis is theoretically driven by integrating a generalized model of incomplete competition that states consumer preferences for more product variety into the familiar Cobb–Douglas production function framework. To conclude, ignoring the existence of incomplete markets and associated heterogeneous price setting behavior leads to biased estimates of factor elasticities. Fortunately, the corresponding price bias can be expressed by two (observable) variables: a) total production at the industry level and b) the firm's market share in the segment of the major product. Consequently, augmenting the productivity equation by those variables would remove the bias. In the empirical part of the paper the price bias elimination method is applied to the manufacturing sector. In general and for consumer goods industries, empirical results suggest application of the method. Price-cost margins obviously differ within and also between industries. Moreover, the widely adopted hypothesis of constant returns to scale cannot be maintained. Further research is needed for intermediate goods industries.

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1 Introduction

Empirical research on productivity and industrial organization widely uses sales and industry–wide deflators as instruments for the corresponding theoretical variables (per–capita–)output and (idiosyncratic) prices. The need for instrumentation is caused by non-observability of output figures and firm specific prices. Unless all firms exhibit identical price–cost margins, the above approach introduces an omitted variable bias into productivity estimates. In particular, scale elasticities are underestimated (Klette and Griliches (1996)). Moreover, heterogeneous market power of firms is neglected. As Klette and Griliches (1996) also pointed out, a promising approach to remove the respective price bias emerging from endogenous and unobserved pricing behavior is to impose sufficient structure on the product demand side of the firm's decision problem. In particular, they use a monopolistic competition model in which they assume (small) and symmetric market shares of firms within broadly defined industries.

The study presented here, extends for asymmetric market shares and substitution elasticities which differ between narrowly defined market segments and broadly defined industries. It uses the most flexible model of incomplete competition that consistently derives firm behavior out of consumer preferences for product variety. Consumer preferences are the only critical assumption in the presented model. A refined version of the widely examined Dixit–Stiglitz–model (Dixit and Stiglitz (1977)) is developed, with the following extensions: First, we allow for asymmetric market shares. Consequently, the model discriminates between relevant market segments which influence the firm specific choice of price on the one hand and the more broadly defined, but still differentiated, industry level on the other hand. The latter has been used in former studies as an instrument to substitute out the omitted variable bias. Second, we formalize substitution possibilities between goods that depend on the aggregation level of the considered market. For example, it seems sensible to assume the elasticity of substitution to be larger at narrowly defined markets in comparison to industry–wide demarcations.

The next section discusses the corresponding demand model and develops the heterogeneous price bias elimination method. A critical assumption will be that firms strictly follow a profit-maximization strategy. Section 3 applies this method to the manufacturing sector. Productivity estimates are performed using a rich plant level data set. One result will be that the method performs sufficiently for consumer goods affiliated industries, but further research is needed for intermediate goods industries. Section 4 concludes.

2 Economic Background

The previous section has pointed out that undetected idiosyncratic price setting of firms has severe consequences in productivity estimates when firm level output is unobserved and deflated sales (or deflated value added) based on an industry–wide deflator is used as an instrument. The main objective of this paper is to present a theoretically consistent method which removes the resulting omitted variable bias and to test it empirically. This section introduces a demand system that provides sufficient economic structure to derive the profit maximizing price–output decision of any individual firm. We allow for incomplete competition and firm level price setting caused by consumer preferences for product variety.

Our starting point is the widely examined (Spence–)Dixit–Stiglitz–model of monopolistic competition (Dixit and Stiglitz (1977)). In extension of Dixit and Stiglitz (1977), we do allow for entry barriers and sunk costs in order to not exclude persistent profits. In addition, the assumption of absence of different market segments within one industry, hence, the assumption of symmetric market shares at the industry level is relaxed.[1]

The next subsection examines the market structure.

2.1 The Demand System: Consumer Preferences for Product Variety under Incomplete Competition

The major advantages of the monopolistic competition model are it's flexibility and the fact that only a few assumptions are required for a rigorous derivation of the results. The critical assumption deals with consumer preferences. Here, the model states CES–type utility functions.

Relaxation of the symmetric market shares assumption can be interpreted as follows: In this paper, we develop a two stage model with ”nested” market definitions: Firm specific pricing within the (relevant) market segment, hence, the segment where the firm and its direct competitors sell their major product forms stage one. Stage one market demarcation is embedded in a broader industry–wide definition which encompasses diverging market segments and corresponds with stage two. Industry and market segment deviate by the degree of substitutability between any two goods or, formally, by elasticity of substitution. Consequently, pricing rules differ between the two stages. Whereas stage one covers idiosyncratic

1 This sets up the basis for the intended extension of existing empirical work which maintains this critical assumption (Klette and Griliches (1996)).

price setting of firms, stage two reflects segment specific price setting relative the average price level within the corresponding industry.[2]

The two stage model is as follows: Firm level demand Q_{it} is determined by the aggregate size of segment Q_{St}, by the firm specific price relative the average price in the market segment P_{it}/P_{St}, and by the demand elasticity with respect to individual price changes, denoted by η_i. Provided consumers maximize utility, η_i is defined by the elasticity of substitution between goods of firm i and representative firm j in segment S:

$$Q_{it} \;=\; Q_{St}\left(\frac{P_{it}}{P_{St}}\right)^{\eta_i} \quad . \tag{1}$$

Stage two extends to the industry level and takes care of the fact that, although belonging to the same industry, substitution possibilities within narrowly defined markets differ significantly from substitution possibilities between separate markets. Correspondingly, at stage two, the focus is on the production share of a particular market segment within an industry. Analogously to equation (1), aggregate volume of market segment Q_{St} is given by the following equation (2):

$$Q_{St} \;=\; Q_{It}\left(\frac{P_{St}}{P_{It}}\right)^{\eta_S} \quad . \tag{2}$$

Notice, that we did not assume elasticity of substitution at the industry level to coincide with elasticity of substitution within the specific market segment. The corresponding demand elasticities are captured by η_S (industry level, equation (2)) and by η_i (segment level, equation (1)). Finally, Q_{It} measures industry demand and P_{It} indicates the average price at the industry level. For simplicity, we consider the demand elasticities η_i and η_S to be time–invariant. Taking logarithms, equations (1) and (2) are rewritten as:

$$\eta_i^{-1} \cdot (\ln Q_{it} - \ln Q_{St}) \;=\; \ln P_{it} - \ln P_{St} \tag{3}$$

and

$$\eta_S^{-1} \cdot (\ln Q_{St} - \ln Q_{It}) \;=\; \ln P_{St} - \ln P_{It} \quad . \tag{4}$$

2 In the empirical section, industries will be defined on a 2/3–digit basis according to ISIC–Rev. 3 classification.

The interpretation of these two equations is straightforward: The (log of the) firm's market share is determined by the (log of) firm level price relative the average price of the firm's competitors and by the similarity between the firm's and the competitor's products. Correspondingly, the relative weight of market segment S within industry I is determined by the similarity between market segments as well as by the difference between segment–specific and industry–average prices.

The next subsection solves the related optimization problem and derives profit maximizing price–cost margins which will be denoted as markup μ.

2.2 Profit Maximization: Heterogeneous Price–Cost Margins

In this subsection an expression for the deviation of idiosyncratic prices from the industry average is provided that counts for both, market specific and industry–wide behavior. Given the assumption that consumers prefer product variety and maximize utility, the solution of the profit maximization problem

$$\max_{Q_i} \pi_i = P_i[Q_i] \cdot Q_i - c[Q_i] \tag{5}$$

yields the well known first order condition:

$$P_i[Q_i] \cdot \left(1 + \eta_i^{-1}\right) \quad \stackrel{!}{=} \quad c'[Q_i], \tag{6}$$

where we have omitted the period index t for simplicity. Solving equation (6) for η_i expresses the demand elasticity in terms of the firm specific markup $\mu_i = P_i/c'$. With a time–invariant markup (6) can be rewritten as:

$$\eta_i = \frac{\mu_i}{1 - \mu_i} \quad . \tag{7}$$

Equation (7) is valid if both, consumers and producers within a particular market segment, strictly follow their optimization strategies. It disentangles the relationship between markups and demand elasticity or, equivalently, between price–cost margins and substitution possibilities. Analogously to η_i, relative changes in the industry weights of market segments due to relative changes in the corresponding average market segment price level are given by η_S with

$$\eta_S = \frac{\mu_S}{1-\mu_S} \quad . \tag{8}$$

Combining (3) and (4) as well as substituting (7) or (8) for the respective demand elasticity leads to the desired expression for idiosyncratic price deviations from the industry average:

$$\ln P_{it} - \ln P_{It} \quad = \quad \left(\mu_i^{-1} - \mu_s^{-1}\right) \cdot (\ln Q_{it} - \ln Q_{St}) \; + \; \left(\mu_s^{-1} - 1\right) \cdot (\ln Q_{it} - \ln Q_{It}) \, . \tag{9}$$

Equation (9) describes the deviation of idiosyncratic price setting from industry–wide average in terms of a) the firm's market share in it's relevant market segment, b) the firm's share in total industry production, and c) the price–costs margins due to market power, measured at different levels of aggregation, hence, representing diverging similarity levels of products. Let us denote (9) as the price–bias–equation. Before resuming this equation in the next subsection, the production function and, in particular, the productivity equation (which measures output per capita) are examined.

2.3 Idiosyncratic Price Levels and the Productivity Equation: The Price Bias Elimination Method

The objective of this subsection is to quantify the potential price bias that emerges in productivity estimates when the unobserved left hand side variable *output* (or output per capita) is instrumented by deflated *sales* (or labor productivity).

Let Q_{it} indicate production of firm i in period t. Then the classical productivity measure *output per capita* opc is denoted by

$$\text{opc} \quad = \quad Q_{it}/L_{it} \quad . \tag{10}$$

Taking logs leads to our *preferred performance measure* $\ln \text{opc}$:

$$\ln \text{opc} \quad = \quad \ln Q_{it} - \ln L_{it} \quad . \tag{11}$$

With respect to our primary focus, the estimation of scale elasticity and potential markups (price–cost margins), we have to examine, whether $\ln \text{opc}$ is observable and, if not, which consequences result for productivity estimates, and how to cope with them, respectively.

Suppose, instead of $\ln \mathrm{opc}$ only deflated labor productivity is measured, together with an industry–wide deflator. Denote the observed variable by prod. Classical empirical results will be biased, if prod deviates from opc. To identify the potential difference between those two variables, equation (11) is rewritten in terms of prod:

$$\mathrm{prod}_{it} \equiv \ln\left((1-s_{\mathrm{m}_{it}})\cdot\frac{P_{it}\,Q_{it}}{P_{It}}\right) - \ln L_{it} \tag{12}$$

$$= \underbrace{\ln(1-s_{\mathrm{m}_{it}})}_{①} + \underbrace{\ln Q_{it} - \ln L_{it}}_{②} \tag{13}$$

$$+ \underbrace{\ln P_{it} - \ln P_{It}}_{③} \quad ,$$

where $(1-s_{\mathrm{m}_{it}})\cdot\frac{P_{it}\,Q_{it}}{P_{It}}$ measures value added, with the cost share of material s_{m}. Let us inspect equation (13): First, with time–invariant material shares, term ① vanishes, if growth rates are considered or panel estimates are performed. Therefore and for simplicity, term ① does not appear in the further argumentation. The price bias elimination method is concerned with grey–boxed terms ② and ③. Since the second term $(\ln Q_{it} - \ln L_{it})$ captures exactly the theoretically preferred performance measure $\ln \mathrm{opc}$, the resulting omitted variable bias is measured by $\ln P_{it} - \ln P_{It}$, hence, term ③.

Now recall equation (9) from the preceding subsection. If respective data contain information on firm–level major product market shares within the relevant segment and on the firm's share in total industry production, the bias could be substituted out. Unfortunately, our manufacturing data do provide firm's market shares, but not shares in total production. Therefore, we rewrite (13) by using (9) and (11) to solve for the unknown share in total production:

$$\mathrm{prod}_{it} = \mu_S^{-1}\cdot\ln Q_{it} - \ln L_{it} + \left(\mu_i^{-1}-\mu_S^{-1}\right)\cdot[\ln Q_{it} - \ln Q_{St}] \tag{14}$$
$$+ \left(1-\mu_S^{-1}\right)\cdot\ln Q_{It} + \Delta_{it}$$

$$= \frac{1}{\mu_S}\mathrm{opc} + \left(\frac{1}{\mu_i}-\frac{1}{\mu_S}\right)[\ln Q_{it} - \ln Q_{St}] + \left(1-\frac{1}{\mu_S}\right)[\ln Q_{It} - \ln L_{it}] + \Delta_{it}, \tag{15}$$

with $\Delta_{it} = \ln(1 - s_{m_{it}})$. The interpretation of equation (15) is straightforward: The price bias in productivity estimates which is caused by heterogeneous and unobserved price setting can be easily and completely eliminated, if information is available on two more variables: i. industry–wide production relative the firm size ($\ln Q_{It} - \ln L_{it}$) and ii. the firm's market share ($\ln Q_{it} - \ln Q_{St}$). As mentioned before, in the illustrating empirical section, the latter will be taken from plant level data (for data description see Carstensen and Brand (1999)). Corresponding industry–wide production levels are available from official statistics (Statistisches Bundesamt (1998, 1996, 1995)).

To summarize the theoretical results, an empirical specification of the labor productivity equation should include two additional regressors: first, industry wide production level related to firm size and, second, the firm's market share. Notice, that this result is theoretically driven and relies on only a few assumptions, namely derives an extended version of the widely recognized Dixit-Stiglitz–model. The next section applies the elimination method and presents estimation results on scale elasticity and price–cost margins. According to it's property of completely eliminating the corresponding omitted variable bias, the presented method will also be denoted as *heterogeneous price control*.

3 Empirical Application: Price–Costs Margins and Scale Elasticities in the Manufacturing Sector

The objective of this section is to empirically test the *heterogeneous price control*. On the one hand, it is important to learn more about the empirical relevance of firm specific pricing and product variety. On the other hand, we are interested in the relative performance of the presented method that discriminates between firm level and industry level markups, in comparison to known methods. The latter assume symmetric market shares and take the elasticities of substitution between goods as given and independent of the aggregation level of the data (Crepon, Desplatz and Mairesse (1999), Klette and Griliches (1996)). As shown in the previous section, when consumers have preferences for product variety and, in addition, firm level output is unobserved, theory suggests the application of the price bias elimination method. Although common practice, it is not sufficient to just deflate value added per capita, since in an environment with preferences for product variety, producers individually choose profit maximizing prices, hence, idiosyncratic prices prevail, at least in the short run.

3.1 The Data

The empirical study is based on representative data that cover the manufacturing sector. Data are taken from three sources: The major data source is the *Hannover Firm Panel (HFP)*, a representative cross–section time–series data set for plants with at least five employees (Lower Saxony, Germany). The sample consists of 1025 privately–owned enterprises and contains annual information over the period from 1993 to 1997 for a total of 2686 observations. The economic content of the yearly questionnaires is similar to British and Australian WIRS (workplace and industrial relations survey, Millward (1993)). The following variables are taken from *HFP*: number of employees, value added, time dummies, sector information and *market share* (component ii. of *heterogeneous price control*).

Industry wide production (component i. of *heterogeneous price control*) is taken from a second data source which is supplied by Federal Statistics Service (Statistisches Bundesamt (1998), Statistisches Bundesamt (1997)). In order to attain sufficient response rates, the *HFP* questionnaires lack physical capital and investment in productive capital. Thus, capital has been imputed from records of the German central bank which cover 85 % of German plants. That source provides information on capital shares on a (*ISIC Rev. 3–3-digits)*$\times$*(sales–classes)* basis (Bundesbank (1999)). Finally, physical capital for each sample unit has been constructed by multiplying firm level sales with the capital share within the associated industry–sales–class cell.

3.2 Specification Issues

In general, we follow common practice and assume that firms produce according to a Cobb–Douglas type production technology.[3] Price–cost margins and scale elasticity are simultaneously estimated with no restriction imposed on factor productivity or pricing, like, for example, constant return to scale.

Output Q_{it} of firm i is produced with classical input factors (labor L_{it}, capital K_{it}). Overall efficiency shifts are summarized in A_{it}:

$$Q = A_{it} \cdot L_{it}^{\alpha_l} \cdot K_{it}^{\alpha_k} \quad , \tag{16}$$

where $A_{it} = \exp(a_{it} + \gamma t)$ is composed of a firm level efficiency term a_{it} and a

3 An issue for future work is the integration of alternative functional forms (e. g. translog type production functions) and the control for heterogeneous input factors (skill composition, technology and machinery equipment etc.).

common time trend γt which captures factor independent technological progress. Consequently, $\ln \text{opc}$ is specified as:

$$\begin{aligned} \ln \text{opc} &= \ln A_{it} + (\alpha_l + \alpha_k - 1) \ln L_{it} + \alpha_k \, (\ln K_{it} - \ln L_{it}) && (17) \\ &= \ln A_{it} + (\text{scale elasticity} - 1) \ln L + \alpha_k \, (\ln K_{it} - \ln L_{it}) \quad . && (18) \end{aligned}$$

Combining equations (15) and (18) and adding a normally distributed error term u_{it} yields:

$$\begin{aligned} \text{prod}_{it} &= \beta_0 + \beta_1 \ln L_{it} + \beta_2 \, (\ln K_{it} - \ln L_{it}) + \beta_3 \, (\ln Q_{It} - \ln L_{it}) && (19) \\ &\quad + \beta_4 \ln (\ln Q_{it} - \ln Q_{St}) + \beta_5 t + u_{it} \quad . \end{aligned}$$

Which estimation procedure is appropriate depends on the distribution of the error term u_{it}. If, for example, $u_{it} \sim iid\, N(0, \sigma^2)$, hence, $\mathrm{E}(\mathbf{uu'}) = diag[\sigma_1^2, \ldots, \sigma_n^2]$ and $\mathrm{E}(\mathbf{X}_{it}\, \mathbf{u}) = \mathbf{0}$, ordinary least squares is applicable. Our estimates rely on a generalized estimation of the covariance matrix (Savin and White (1977), White (1980)), since heteroscedasticity and serial correlation have been detected. Thus, autocorrelation– and heteroscedasticity–robust t-values are documented (tables 3–5). For unobserved heterogeneity has been controlled for in panel estimates (tables 6 and 7).

3.3 Results

Description of the variables and descriptive statistics are depicted in table 2. The remaining tables show the econometric results of the application of the price bias elimination method. Specification tests for preparatory estimates (not documented here) detected heteroscedasticity and autocorrelation. Therefore, GLS estimations with an autocorrelation resistent and heteroscedasticity consistent covariance matrix are performed. Basic econometric models appear in Table 3. These models treat the manufacturing sector as a whole. Models 1 to 3 suppress the additional regressors that aim at removing the price bias and serve as a basis for comparisons. Model 4 introduces the price bias elimination method. Again for reasons of comparison, model 5 presents GLS results, which are corrected for first order serially correlated residuals following the method of Prais–Winsten (see Stata (2001)).

Tables 4 and 5 correspond with basic model 4, but present industry specific results, where we distinguish 9 industries based on a 2/3–digit ISIC–Rev. 3 classification. Fixed Effects results are shown in tables 6 and 7. In addition, Random Effects estimations have been performed when the LM–test pointed out the existence of random effects and the Hausman specification test could not reject the hypothesis that the unobserved firm specific effect is uncorrelated with other regressors. These additional estimates are not documented, since results do not differ much from FE results. Moreover, because of the weak and mixed results of the fixed effects estimates and with respect to small sample–size, we concentrate further interpretation on tables 3 to 5.

Various specification tests appear in the lower part of these tables. In addition to standard tests, they mainly deal with the explanatory power of the price bias elimination method. First, the overall relevance of *heterogeneous price control* is tested. Second, the hypothesis of identical substitution possibilities within and between market segments is investigated (identical markups). Third, the statement of marginal cost pricing is questioned and finally, the validity of constant returns to scale is tested. If, for example, the hypotheses of identical markups is rejected, the presented price bias elimination method outperforms existing methods which are merely based on industry demand (Klette and Griliches (1996) and Crepon et al. (1999)).

Table 3 includes three basic models, which impose the restriction of homogeneous product pricing within sectors (model 1 to model 3). Model 1 and model 2 are nested in model 3. Model 1 neglects technical change and excludes sector specific influences on productivity. Model 2 extends model 1 by controlling for disembodied technical change. Model 3 extends model 2 by sector controls. Wald tests for joint significance suggest both, the inclusion of time controls and of sector controls. Without exception, the labor and capital coefficients are highly significant. Sector and time controls are significant at the 1%–percent level, where included. The Hypothesis that no variables have been omitted as well as the hypothesis of constant returns to scale are rejected for any of the three basic models.

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Eventually, the *heterogeneous price control* is introduced in model 4 (additional variables *industry output* and *market share*). The hypothesis of homogeneous pricing is rejected at the 1%–level. Thus, price control is not irrelevant. Moreover, firm level markups do not coincide with markups at higher aggregation levels

(5%–level), hence, existing models seem to be improved. At the firm level, the difference between product price and marginal cost is significant at the 5%–level. The estimated markup $\widehat{\mu}_i$ amounts to 9.2%. Like for the previous models, the hypothesis of constant returns to scale is rejected at the 1%–level (see table 1).

The following tables 4 and 5 replicate model 4 for 9 industry groups separately. Here, the thirty sectors are aggregated to 9 groups (2/3–digit ISIC–Rev. 3 classification, see Statistisches Bundesamt (1996, 1997)). Table 4 presents the results for the food industry *DA* in column 1. Column 2 represents ceramics/glass (*DI*). Textile, leather, and clothing (*DB* and *DC*) appear in column 3. Wood industry (*DD*) is documented in column 4.

Table 5 encompasses the other five industry groups: The results for paper and print (*DE*) appear in column 1. The chemical industry, rubber and plastics are presented in column 2 (*DF*, *DG* and *DH*). Productivity estimates for metal products (*DH*) can be found in column 3. Machinery and car building (*DF* and *DG*) appear in column 4. The last column 5 documents the results for electrical equipment and data processing/IT (*DL*).

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The upper part of the tables is again split into three subparts: a) classical input factors labor and capital, b) technological progress control and additional sector controls (where adequate), and c) the variables to eliminate the price bias. The lower part includes specification tests. Our focus during interpretation is on the three hypotheses on heterogeneous pricing and market power. First, the joint significance of the heterogeneous price control variables is tested. For example, the bold faced value **(0.04)** in column 4 (table 4) indicates for the wood products industry that price setting is endogenous and heterogenous the 5%–level. The second hypothesis $\mu_i = \mu_S$ states that markups are identical across aggregation levels, which is equivalent to the hypothesis that the elasticity of substitution between any to goods within one market segment is the same as across market segments and sectors within the industries groups. For the above industry, this hypotheses is rejected at the 5%–level (see **(0.03)**), indicating that the price bias elimination method which has been developed in this paper improves existing literature.

For five industries these differences in demand elasticity are significant: Wood products, paper and printing, metal products, machinery, and electrical equipment. These industries could be regarded as supplying (differentiated) durable goods with idiosyncratic product characteristics. Thus, empirical evidence is in favor of the theoretical predictions on idiosyncratic market power in a differentiated products environment.

The third hypotheses $p_i = C'[Q_i]$ is concerned with variations within estimated markups compared to their size. The corresponding null hypothesis states that $\mu_i = 1$. If this hypothesis is rejected, price–cost margins at the firm level are statistically proven and durable rents exist at the firm level. At a second stage such rents could be part of a bargaining process between management and worker representation, an interesting question for further research. Table 1 gives an impression on the size of such markups (and of the simultaneously estimated scale elasticities).

Table 1: Firm level price–cost margins and scale elasticities [a]

	All [b]	Food [b]	Ceramics Glass [b]	Textile Clothing [b]	Wood Products [b]	
Markup $\widehat{\mu}_i$	**1.092*** **(0.03)**	0.812 (0.69)	0.963 (0.90)	6.695 (0.11)	3.146 (0.41)	
		Paper Printing [b]	**Chemicals [b]**	**Metal [b]**	**Machinery [b]**	**Electr. Eq. IT [b]**
		1.522* **(0.03)**	0.915 (0.65)	0.952 (0.99)	**1.259†** **(0.09)**	0.799 (0.35)

	All [b]	Food [b]	Ceramics Glass [b]	Textile Clothing [b]	Wood Products [b]	
Scale Elasticity	**1.024**** **(0.00)**	**0.99*** **(0.03)**	**1.017**** **(0.00)**	0.432 (0.77)	**1.157**** **(0.00)**	
		Paper Printing [b]	**Chemicals [b]**	**Metal [b]**	**Machinery [b]**	**Electr. Eq. IT [b]**
		1.025** **(0.00)**	**1.052**** **(0.00)**	**0.99**** **(0.00)**	**1.047**** **(0.00)**	**1.019**** **(0.00)**

level of sign.: †: 10% ∗: 5% ∗∗: 1%
[a] Data source: The Hannover Firmpanel (1994–1997); Statistisches Bundesamt ; Bundesbank.
[b] Level of significance in parentheses.

Although markups seem to reach a considerable amount, the marginal–cost–pricing hypotheses and, correspondingly, a long run optimum with zero profits could not be rejected for seven of the nine industries. Significant deviation from marginal cost pricing is only found for firms operating in the print and paper industry (5%–level) or in machinery (borderline significance: 10%–level). The representative firm within paper and print earns a markup of 62%. The counterpart within machinery charges price which exceed marginal costs by 26%.

Given the size of the markup, the corresponding demand elasticity can by calculated (see equation (7)). For the manufacture of machinery we estimate a demand elasticity of -4.9, compared to -6.0 in Klette and Griliches (1996). A result which could indicate that demand for machinery product in Norway is more elastic than in Germany, hence, implying larger market power. In contrast to Klette and Griliches (1996), there is no evidence of firm level markups for the manufacture of electrical apparatus and supplies (including IT systems), although the hypothesis of homogeneous price setting is clearly rejected. However, the specification is questionable, since omitted variables are detected, and if we control for unobserved firm specific effects (within estimator), the price bias elimination variables completely lose significance. Maybe, firm specific markups and markups at the industry level of electrical equipment are rather stable.

As noted by Klette and Griliches (1996), empirical research on the issue of imperfect competition and scale economies is rather controversial and still an open question. If output prices are unknown, heterogeneous and endogenous, estimates of factor elasticities and, consequently, of scale elasticity will be biased. Scale elasticity will be biased downwards if firms have market power, hence if $\mu_i > 1$. Controlling for idiosyncratic pricing, the hypothesis of constant returns to scale (crts) has been tested for each of the nine industries. The results are interesting (see also table 1): First, those industries which also show heterogeneous and idiosyncratic pricing show slightly increasing return to scale (paper and printing: 1.03, machinery: 1.05). Moreover, increasing returns to scale are prevalent for ceramics/glass (1.02), wood products (1.16), chemicals (1.05), electrical equipment/IT (1.02). Third, slightly decreasing returns to scale are proven for the food industry (0.99) and for metal products (0.99). The relatively large scale elasticity for chemical products coincides with expectations. In general, scale elasticities are smaller in our sample than in Klette and Griliches (1996): They found values of 1.09 for machinery and 1.07 for electrical equipment.

The Ramsey test detects omitted variables for the food industry, for chemicals/plastics and for electrical equipment. Here, an issue for future work is to control for heterogenous input, such as skilled work and investment in further training. A more elaborated specification of technological progress, for example embodied in input factors is another task for future research on heterogeneous pricing.

4 Concluding Remarks

It is widely known that idiosyncratic price setting behavior and market power of firms result in an omitted variable bias for productivity estimates, if (unobserved) firm level output is instrumented by deflated sales or labor productivity. However, with regard to lacking data it is still common to ignore the bias and assume industry–common pricing rules when estimating factor and scale elasticities.

This paper has suggested usage of a correction method which eliminates the corresponding bias and allows market specific pricing rules in addition to industry–wide rules. This method has been derived theoretically on the basis of a well defined demand system, which imposed sufficient structure on the firm level optimization problem.

In addition, the price bias elimination method has been applied and tested empirically with German manufacturing data. If statistically proven, price–cost margins and slightly increasing returns to scale are found simultaneously. Although estimation results are quite convincing for traditional durable goods industries, further work is needed for industries which produce intermediate products.

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A Appendix: Variable Description and Estimation Results

Table 2: Variable Description

Variable	Mean	Std. Dev..	N	Description [a]
$\ln K_{it} - \ln L_{it}$	9.826	0.688	2124	capital intensity (in logs),
$\ln L_{it}$	8.797	1.111	2124	labor input (annual average of number of employees, in logs),
$\ln R_{it} - \ln L_{it}$	10.913	0.522	2124	labor productivity (dependent variable), in logs,
industry–wide production	1.708	0.211	1484	log of total production of industry, defined on a 2/3–digit basis according to ISIC–Rev. 3 classification ($\ln Q_{It} - \ln L_{it}$),
market share	1.678	1.242	1638	share of the firm's major product in the relevant market segment: $\ln Q_{it} - \ln Q_{St}$ (in logs),
sector control			2124	dummy variable for sector (30 Sectors, classification: 4–digit according WZ 93 (similar ISIC Rev. 3)).
time control			2124	dummy variable for year of observation (1993, 1994, 1995, 1996).

[a] Deflated value in EUR.

Table 3: Productivity equations (basic models), dependent variable: deflated labor productivity, method: FGLS with autocorrelation resistent and White HCCM (M 1-4), Prais-Whinston-AR(1)-correction with robust standard errors (M 5)[a]

	Model 1 [b]	**Model 2** [b]	**Model 3** [b]	**Model 4** [b]	**Model 5** [b]
$\ln L_{it}$	0.0409^{**} (0.0123)	0.0413^{**} (0.0122)	0.0267^{*} (0.0112)	0.0214^{*} (0.0010)	$0.0177^{\dagger}$ (0.0111)
$\ln K_{it} - \ln L_{it}$	0.5932^{**} (0.0257)	0.7148^{**} (0.0257)	0.6985^{**} (0.0324)	0.7105^{**} (0.0322)	0.7209^{**} (0.0280)
time control	—	yes*	yes*	yes**	yes**
sector control	—	—	yes**	yes**	yes**
industry production [c]	—	—	—	0.1141^{*} (0.0511)	0.1163^{*} (0.0466)
market share [d]	—	—	—	0.0300^{**} (0.0096)	0.0188^{*} (0.0083)
const.	5.1894^{**} (0.2642)	5.1999^{**} (0.2623)	4.1657^{**} (0.3133)	3.8927^{**} (0.3337)	3.5587^{**} (0.3788)
No. of cases	1139	1139	1139	1139	1139
R^2	61.87	62.03	70.64	71.10	98.44
RMSE	0.328	0.328	0.292	0.290	0.217
Ramsey–Test [e1] / DW–Stat. [e2]	**(0.01)**	**(0.01)**	**(0.01)**	(0.18)	–/ **1.72**
H_0 : elimination method irrelevant [f]	—	—	—	**(0.01)**	**(0.01)**
$H_0 : \mu_s = \mu_i$ [g]	—	—	—	**(0.01)**	**(0.02)**
$H_0 : p_i = C'[Q_i]$ [h]	—	—	—	**(0.03)**	**(0.02)**
H_0 : constant RTS [i]	**(0.00)**	**(0.00)**	**(0.00)**	**(0.00)**	**(0.00)**

level of sign.: †: 10% ∗: 5% ∗∗: 1%

[a] Data source: The Hannover Firmpanel (1994–1997); Statistisches Bundesamt ; Bundesbank.

[b] Standard deviation in parentheses.

[c] Formally: $\ln Q_{It} - \ln L_{it}$, classification of industries according to WZ 93 (∼ ISIC–Rev. 3, Bald-Herbel and Herbel (1995), Nowack and Weisbrod (1995), Statistisches Bundesamt (1998)).

[d] Market share of the firm, demarcation: market, where the major product is placed, $\ln Q_{it} - \ln Q_{St}$.

[e1] Hypothesis: No omitted variables, rejection level in parentheses. [e2] Hypothesis: No positive or negative serial autocorrelation (boldfaced if rejected 5%-level).

[f] Joint significance of the additional regressors.

[g] Test on the relative performance of the *heterogeneous price control* method compared to Klette and Griliches (1996) and Crepon et al. (1999), rejection level for the hypotheses of common markups.

[h] Hypothesis: marginal cost pricing is effective, rejection level in parentheses.

[i] Hypothesis: constant returns to scale, rejection level in parentheses.

Table 4: Preferences for product variety and heterogeneous price setting, separate estimates for Food, Ceramics/Glass, Textile/Clothing and Wood products, dependent variable: deflated value added per capita, method: FGLS with autocorrelation resistent and White HCCM[a]

	Food [b]	**Ceramics/ Glass** [b]	**Textile/Leather Clothing** [b]	**Wood products** [b]
$\ln L_{it}$	−0.0111 (0.0662)	0.0169 (0.0254)	−0.0621 (0.0599)	0.0596** (0.0196)
$\ln K_{it} - \ln L_{it}$	0.7296** (0.0801)	0.9242** (0.0759)	0.7059** (0.1033)	0.6770** (0.0474)
time control	yes	yes	yes	yes†
sector control	—	yes	yes**	yes
industry production [c]	−0.2321 (0.5707)	−0.0157 (0.1246)	0.8906 (0.5720)	0.6213 (0.9309)
market share [d]	0.0377 (0.0447)	0.0227 (0.0285)	0.0400 (0.0402)	−0.0608* (0.0235)
const.	4.3173* (1.7881)	1.4685† (0.8512)	2.8989* (1.2763)	2.6659 (2.1410)
No. of cases	119	125	68	94
R^2	77.75	76.43	64.22	76.52
Ramsey–Test [e]	**(0.01)**	(0.11)	(0.21)	(0.77)
H_0 : elimination method irrelevant [f]	(0.61)	(0.69)	(0.24)	**(0.02)**
$H_0 : \mu_s = \mu_i$ [g]	(0.41)	(0.43)	(0.33)	**(0.01)**
$H_0 : p_i = C'[Q_i]$ [h]	(0.69)	(0.90)	(0.11)	(0.52)
H_0 : constant RTS [i]	**(0.03)**	**(0.00)**	(0.77)	(0.73)

level of sign.: †: 10% ∗: 5% ∗∗: 1%

[a] Data source: The Hannover Firmpanel, Wave 1 to 4 (1994–1997); Statistisches Bundesamt ; Bundesbank.
[b] Standard deviation in parentheses.
[c] Formally: $\ln Q_{It} - \ln L_{it}$, classification of industries according to WZ 93 (∼ ISIC–Rev. 3, Bald-Herbel and Herbel (1995), Nowack and Weisbrod (1995), Statistisches Bundesamt (1998)).
[d] Market share of the firm, demarcation: market, where the major product is placed, $\ln Q_{it} - \ln Q_{St}$.
[e] Hypothesis: No omitted variables, rejection level in parentheses.
[f] Joint significance of the additional regressors.
[g] Test on the relative performance of the *heterogeneous price control* method compared to Klette and Griliches (1996) and Crepon et al. (1999), rejection level for the hypotheses of common markups.
[h] Hypothesis: marginal cost pricing is effective, rejection level in parentheses.
[i] Hypothesis: constant returns to scale, rejection level in parentheses.

Table 5: Preferences for product variety and heterogeneous price setting, separate estimates for Paper/Printing, Chemicals/Plastics, Metal products, Machinery, Electrical Equipment, dependent variable: deflated value added per capita, method: FGLS with autocorrelation resistent and White HCCM[a]

	Paper-/ Printing [b]	Chemicals/ Plastics [b]	Metal products [b]	Machinery/ [b]	Electrical Equipment [b]
$\ln L_{it}$	0.0147 (0.0258)	0.0569** (0.0142)	−0.0053 (0.0266)	0.0342 (0.0251)	0.0226 (0.0264)
$\ln K_{it} - \ln L_{it}$	0.7097** (0.0639)	0.6029** (0.0918)	0.5066** (0.0539)	0.6258** (0.0772)	0.7029** (0.1078)
time control	yes**	yes	yes	yes*	yes
sector control	yes**	yes**	yes*	yes*	yes
industry production [c]	0.4329* (0.1864)	−0.0983 (0.2164)	−0.0175 (0.1499)	0.2750† (0.1681)	−0.1963 (0.3057)
market share [d]	0.0322* (0.0172)	−0.0049 (0.0184)	0.0492* (0.0220)	0.0689** (0.0246)	0.0539* (0.0231)
const.	3.1223** (0.7105)	5.0934** (0.9340)	6.3093** (0.7042)	4.2182** (0.9079)	4.9276** (1.1982)
No. of cases	107	164	111	210	94
R^2	69.50	74.20	47.06	53.96	79.39
Ramsey–Test [e]	(0.84)	**(0.00)**	(0.23)	(0.12)	**(0.01)**
H_0 : elimination method irrelevant [f]	**(0.01)**	(0.89)	**(0.08)**	**(0.02)**	**(0.05)**
$H_0 : \mu_s = \mu_i$ [g]	**(0.05)**	(0.79)	**(0.03)**	**(0.01)**	**(0.03)**
$H_0 : p_i = C'[Q_i]$ [h]	**(0.03)**	(0.65)	(0.99)	**(0.09)**	(0.35)
H_0 : constant RTS [i]	**(0.00)**	**(0.00)**	**(0.00)**	**(0.00)**	**(0.00)**

level of sign.: †: 10% ∗: 5% ∗∗: 1%

[a] Data source: The Hannover Firmpanel, Wave 1 to 4 (1994–1997); Statistisches Bundesamt; Bundesbank.

[b] Standard deviation in parentheses.

[c] Formally: $\ln Q_{It} - \ln L_{it}$, classification of industries according to WZ 93 (∼ ISIC–Rev. 3, Bald-Herbel and Herbel (1995), Nowack and Weisbrod (1995), Statistisches Bundesamt (1998)).

[d] Market share of the firm, demarcation: market, where the major product is placed, $\ln Q_{it} - \ln Q_{St}$.

[e] Hypothesis: No omitted variables, rejection level in parentheses.

[f] Joint significance of the additional regressors.

[g] Test on the relative performance of the *heterogeneous price control* method compared to Klette and Griliches (1996) and Crepon et al. (1999), rejection level for the hypotheses of common markups.

[h] Hypothesis: marginal cost pricing is effective, rejection level in parentheses.

[i] Hypothesis: constant returns to scale, rejection level in parentheses.

Table 6: Preferences for product variety and heterogeneous price setting, separate estimates for Food, Ceramics/Glass, Textile/Clothing and Wood products, dependent variable: deflated value added per capita, method: Fixed Effects[a]

	All plants [b]	Food [b]	Ceramics/ Glass [b]	Textile/Leather Clothing [b]	Wood products [b]
$\ln L_{it}$	−0.0753 (0.0841)	−0.2149 (0.2271)	0.0235 (0.2358)	−0.2283 (0.5394)	−0.3083 (0.2129)
$\ln K_{it} - \ln L_{it}$	0.9152** (0.0519)	1.5949** (0.2271)	0.9585** (0.1826)	1.0826* (0.0401)	0.6131** (0.1590)
time control	yes**	yes**	yes	yes	yes
industry production [c]	0.1213* (0.0492)	0.8215† (0.4720)	−0.0066 (0.1772)	0.5326 (0.5031)	−0.8226 (1.2358)
market share [d]	0.0011 (0.0134)	0.0319 (0.0459)	0.0581 (0.0399)	0.0239 (0.6047)	0.0022 (0.0551)
const.	1.9859** (0.7695)	−6.4995** (3.1629)	0.9722 (2.6167)	0.2049 (4.7759)	8.0965** (3.8298)
N (cases;groups)	1139;566	119;58	125;61	68;32	94;50
R^2	56.52	76.13	75.62	38.23	13.68
Hausman–Test [e]	**(0.00)**	(0.26)	(0.94)	(0.86)	(0.38)
H_0 : elimination method irrelevant [f]	**(0.04)**	(0.18)	(0.35)	(0.52)	(0.80)
$H_0 : \mu_s = \mu_i$ [g]	(0.94)	(0.84)	(0.16)	(0.69)	(0.96)
$H_0 : p_i = C'[Q_i]$ [h]	**(0.01)**	(0.08)	(0.97)	(0.29)	(0.51)
H_0 : constant RTS [i]	**(0.00)**	(0.48)	**(0.00)**	(0.35)	(0.09)

level of sign.: †: 10% ∗: 5% ∗∗: 1%

[a] Data source: The Hannover Firmpanel, Wave 1 to 4 (1994–1997); Statistisches Bundesamt; Bundesbank.

[b] Standard deviation in parentheses.

[c] Formally: $\ln Q_{It} - \ln L_{it}$, classification of industries according to WZ 93 (∼ ISIC–Rev. 3, Bald-Herbel and Herbel (1995), Nowack and Weisbrod (1995), Statistisches Bundesamt (1998)).

[d] Market share of the firm, demarcation: market, where the major product is placed, $\ln Q_{it} - \ln Q_{St}$.

[e] Hypothesis: Firm specific effects ν_i are uncorrelated with regressors (rejection level for RE-model). F-Test (H_0 : all $\nu_i = 0$) always rejected at the 1%-level.)

[f] Joint significance of the additional regressors.

[g] Test on the relative performance of the *heterogeneous price control* method compared to Klette and Griliches (1996) and Crepon et al. (1999), rejection level for the hypotheses of common markups.

[h] Hypothesis: marginal cost pricing is effective, rejection level in parentheses.

[i] Hypothesis: constant returns to scale, rejection level in parentheses.

Table 7: Preferences for product variety and heterogeneous price setting, separate estimates for Paper/Printing, Chemicals/Plastics, Metal products, Machinery, Electrical Equipment, dependent variable: deflated value added per capita, method: Fixed Effects[a]

	Paper-/ Printing [b]	**Chemicals/ Plastics** [b]	**Metal products** [b]	**Machinery/** [b]	**Electrical Equipment** [b]
$\ln L_{it}$	0.0796 (0.1618)	0.0562 (0.1334)	0.0394 (0.3386)	−0.4250 (0.2704)	−0.6447 (0.3192)
$\ln K_{it} - \ln L_{it}$	1.0245** (0.1239)	0.8868** (0.1207)	0.7632** (0.1885)	0.8958** (0.1355)	1.2082** (0.1608)
time control	yes**	yes	yes	yes**	yes
industry production [c]	0.1663 (0.1832)	−0.0065 (0.2012)	−0.0478 (0.2181)	0.3835** (0.1410)	−0.3341 (0.4223)
market share [d]	−0.0525 (0.0393)	−0.0065 (0.0161)	0.1402* (0.0641)	−0.01516 (0.0348)	−0.0358 (0.0355)
const.	0.1727 (1.832)	2.0493 (1.5537)	3.3158 (2.854)	3.5679† (1.8982)	3.4582 (2.8647)
N (cases;groups)	107;57	164;85	111;61	210;103	94;44
R^2	60.79	73.51	38.81	53.49	12.94
Hausman–Test [e]	**(0.00)**	(0.07)	(0.97)	(0.13)	**(0.05)**
H_0 : elimination method irrelevant [f]	(0.27)	(0.92)	(0.09)	**(0.01)**	(0.48)
$H_0 : \mu_s = \mu_i$ [g]	(0.18)	(0.68)	**(0.03)**	**(0.05)**	(0.31)
$H_0 : p_i = C'[Q_i]$ [h]	(0.37)	(0.97)	(0.83)	**(0.01)**	(0.41)
H_0 : constant RTS [i]	**(0.01)**	**(0.00)**	**(0.00)**	**(0.00)**	**(0.00)**

level of sign.: †: 10% *: 5% **: 1%

[a] Data source: The Hannover Firmpanel, Wave 1 to 4 (1994–1997); Statistisches Bundesamt; Bundesbank.

[b] Standard deviation in parentheses.

[c] Formally: $\ln Q_{It} - \ln L_{it}$, classification of industries according to WZ 93 (∼ ISIC–Rev. 3, Bald-Herbel and Herbel (1995), Nowack and Weisbrod (1995), Statistisches Bundesamt (1998)).

[d] Market share of the firm, demarcation: market, where the major product is placed, $\ln Q_{it} - \ln Q_{St}$.

[e] Hypothesis: Firm specific effects ν_i are uncorrelated with regressors (rejection level for RE-model). F-Test (H_0 : all $\nu_i = 0$) always rejected at the 1%-level.

[f] Joint significance of the additional regressors.

[g] Test on the relative performance of the *heterogeneous price control* method compared to Klette and Griliches (1996) and Crepon et al. (1999), rejection level for the hypotheses of common markups.

[h] Hypothesis: marginal cost pricing is effective, rejection level in parentheses.

[i] Hypothesis: constant returns to scale, rejection level in parentheses.