Firm-level price information and the production function estimation*

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Abstract

In order to estimate the firm's production function it is usual to deflate the firm's revenue by an industry price index. As shown by Klette and Griliches (1996), this procedure introduces an omitted variable problem, defined by the difference between the firm's output price and the industry price index. A possible solution is to deflate the revenue by a firm's output price index. In this paper we show that the omitted variable problem does not vanish if this firm's price index is obtained using information on price variation or rate of growth. In this case, the inability to observe the price levele in the base period introduces an unobservable fixed effect. We propose a modification of Olley and Pakes (1996) and Ackerberg's et al (2008) method to correct for this problem and apply it to Spanish manufacturing data.

Keywords: production function; productivity estimation..

JEL Classification: L11,L60

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1. Introduction

1.1. The Issue.—

The estimation of production functions has recently surged with the advent of new micro data sets with abundant of information on firm's inputs, markets, etc. On the one hand, this gave rise to the appearance of new approaches to treat the traditional endogeneity or selectivity problems, such as the one proposed by Olley and Pakes (1996) or Levinsohn and Petrin (2003). On the other, new problems with the estimation of the production function have been pointed out[1].

One of such problems appears when firm-level data on physical quantities of output is non observable and revenues or sales are used instead. The standard approach in the literature has been to deflate firm-level sales by an industry wide producer index to eliminate the price effects.[2] This correction has two major implications: First, the coefficients of the production function will be potentially biased if the price error (the difference between a firm's price and the industry price index) is correlated with the firm's input choices, i.e. the omitted price variable bias (Klette and Griliches, 1996).[3] Secondly, the estimation of total factor productivity (TFP) measure revenue instead of physical productivity, confounding productivity differences across plants with demand shifts or market power variation.[4]

1.2. Previous empirical literature.—

There is a wide empirical literature that estimate production functions, in most of them the omitted price variable bias was ignored or assumed away. In other cases, the pro-

[1] See Bartelsman and Doms (2000), Van Biesebroeck (2007) or Van Beveren (2010) for surveys on the productivity estimation methods and problems.

[2] The problem is similar with inputs, since input prices (like output prices) are typically unavailable, quantities of inputs are usually proxied by deflated values of inputs.

[3] Klette and Griliches (1996) argue that those estimators of the production function that do not deal with this omitted variable problem are inconsistent.

[4] In almost all empirical applications the omitted price variable bias was ignored or assumed away. In other cases the production function is reinterpreted as a sales generation function (see Fernandes and Pakes, 2008).

duction function is reinterpreted as a sales generation function (see Fernandes and Pakes, 2008). Only recently, a number of papers have focused on this problem trying to separate influences of idiosyncratic productivity and demand. Some papers, (e. g. De Loecker (2010), Levinshon and Melitz (2005) or Doralzeski and Jaumandreu (2010)) have proposed a framework which accounts for this problem by introducing a demand system in the standard production function framework. This framework generally assumes that firms in the same industry belong to the same market and face a unique demand elasticity.[5] This is a sensible assumption in very narrow defined industries or with homogeneous goods.

Alternatively, a number of papers deal with the omitted output price bias using surveys that reports variations in (or levels of) output prices at the firm level (e.g. Eslava et al (2004), Mairesse and Jaumandreu (2005), Ornaghi (2007, 2008), Foster et all. (2008)). Information about prices at the firm level make it possible to build a firm specific price index to deflate the firm's total revenue.[6]

1.3. Contribution.—

In this paper we show that the type of information on the firm's output price is determinant to solve the price bias. When the firm's price index is obtained using price growth information (and not price level) then the omitted price variable bias is not eliminated due to the price level at the base year is not observed. There is an initial condition problem in the recursion formula needed to obtain the price index from the price rate of change. In other words, the price level in the base period is an unobservable fixed effect when the available information is only on the firm's output price growth.

This initial condition problem can be ignored by assuming that all firms have the same price level at the base year, i.e. normalized to one. Hence, under this assumption, all the firms in the market have the same output price in the base year. Notice that the base year is any year in the lifecycle of a firm and the rate of price growth clearly depends on the

[5] De Loecker (2010) considers a demand system where elasticities of demand differ by product segment.

[6] For example, the Spanish Encuesta de Estrategias Empresariales or the French panel reports the firm's output price growth while the Colombian Encuesta Anual de Manufacturas (EAM) reports the price level and quantity of each subproduct produced by the firm.

initial true value of the price level at the base year. Therefore, assuming that all the firms in the market have the same price level at a particular year (neither before nor after) could sound like a particularly severe assumption.

In this paper we estimate firm's productivity using a Spanish firm survey that reports data on the firm's output price rate of growth to estimate the firm production function. We treat the price level in the base year as an unobservable fixed effect and propose a modification of the first stage of the Olley and Pakes (1996) (OP henceforward) approach in order to take into account this unobservable fixed effect. The basic idea is to use Baltagi and Li (2002) semiparametric partial linear model with fixed effect estimator in the first stage. This procedure could be generalized to estimation of production functions with two unobservable effects, being one of them a fixed effect.

Our results show that, when estimating using the OP method correcting for an unobservable fixed effect, the estimates of the capital parameters are generally higher than when not correcting or comparing to those obtained by traditional panel data fixed effect approach (Ornaghi, 2006, 2008).

In order to make the paper self-contained, in the next section we discuss the problem that appears when using the industry price index to deflate total revenue. In section 2 we explain the omitted price variable bias. In section 3 we discuss what happens when we use the firm's output price recovered from information on the output price growth to deflate total revenue. In section 4 we discuss a modification to OP methods to take into account the unobservable fixed effect and present the estimation results. In section 5 we conclude.

2. The price bias problem: Total revenue and industry price index

In this section we present the problem that appears when the industry price index is used to deflate total revenue, following Klette and Griliches (1996). Let us assume that the firm's i production function at time t is given by

$$Q_{it} = L_{it}^{\beta_l} K_{it}^{\beta_k} M_{it}^{\beta_m} \exp\left(\omega_{it} + \eta_{it}\right) \tag{1}$$

where Q_{it} stands for quantity produced by firm i at time t, L_{it} are the number of workers with a permanent and a fixed-term contract respectively, K_{it} is capital, M_{it} represents materials and $\beta_l, \beta_k, \beta_m$ are the parameters of the production function. ω_{it}, represents the productivity shock while, η_{it} represents all those shocks that affect production but cannot be anticipated or predicted by the firm. Taking natural logs we obtain

$$q_{it} = \beta_l l_{it} + \beta_k k_{it} + \beta_m m_{it} + \omega_{it} + \eta_{it} \tag{2}$$

Equation (2) can only be estimated if we have information of the quantity produced by the firm. However, this sort of information is traditionally absent from surveys. Mostly all empirical papers use the firm's total revenue deflated by an industry price index as a proxy of the physical quantity. Given the firm's i total revenue $R_{it} = P_{it}Q_{it}$, where P_{it} is the firm's output price, deflating by an industry price index, P_{It}, we get $\widetilde{R}_{it} = P_{it}Q_{it}/P_{It}$ or, in logs we have

$$\widetilde{r}_{it} = r_{it} - p_{It} = q_{it} + (p_{it} - p_{It}) \,. \tag{3}$$

Observe that the firm's revenue deflated by the industry price index equals the firm's output plus the difference between the firm's output price level and the industry price level, $(p_{it} - p_{It})$. This difference is unobservable and captures the relative price variations of the firm's output with respect to the general price index, i.e a relative price (Klette and Griliches 1996; Melitz and Levinsohn 2002; Melitz, 2000). Substituting equation (3) in (2) we get,

$$\widetilde{r}_{it} = \beta_P l_{it}^P + \beta_T l_{it}^T + b\beta_k k_{it} + \beta_m m_{it} + \omega_{it} + \eta_{it} + (p_{it} - p_{It}) \,. \tag{4}$$

This equation has been called the revenue or sales production function in order to emphasize that total revenue has been deflated using the industry price index and, hence, we do not have the firm's output as the dependent variable (Fenandes and Pakes, 2008; Mairesse and Jaumandreu, 2005). The estimates of capital, labor and scale elasticities could be biased if this omitted factor affects the input decisions.

Traditionally, the omitted relative price variation has been ignored. Though usually not made explicit, this implies either assuming that firms are in a perfect competitive market, or that this omitted variable is orthogonal to the input variables and the productivity shock. Nonetheless, firm generally operate in non-competitive environments and its difficult to support that firm's relative price variations are independent of input demand or productivity.

There are at least two possible solutions to this problem. The first one is to introduce additional assumptions and follow a more structural approach. For example, if it is assumed that all the firms in an industry face the same constant elasticity demand curve conditional on the output of the other firms, the coefficients estimated from the above equation will reflect the original production function coefficients divided by one minus the inverse elasticity of demand. Hence, if we can obtain an estimate of this elasticity we could correctly estimate the parameters of the production function (Ornaghi, 2007; de Loecker, 2004; de Santos, 2008; Klette and Griliches 1996; Melitz and Levinsohn 2002). A second approach is an instrumental variable approach, though it seems particularly difficult to find an excluded variable that clears the co-variation of relative prices and inputs but does not affect output (Ackerberg et al. 2007).

In sum, in the absent of observations on the firm's output price an important new set of assumptions are needed in order to recover the parameters of the production function.

A natural way to tackle the omitted variable problem is to use a firm specific output price index to deflate the firm's revenue. However, in the next section we show that the type of information on the firm's output price needed to construct the index is determinant to solve the omitted variable problem. When the firm's price index is obtained using price growth information (and not price level) then the omitted price variable problem is not entirely absent because the price in the base year is not observed, it is an unobservable fixed effect. In other terms, there is an initial condition problem in the construction of the price index, because the initial price in the recursion formula needed to obtain the price index from information on price growth is not observed.

3. Output price growth information: unobservable fixed effect

There are several firms industry surveys that report some sort of information on the firm's output price (Spain, France or Colombia). The Spanish Firm's Strategy Survey or the French panel reports the firm's output price growth while the Colombian Encuesta Anual de Manufacturas (EAM) reports the price level and quantity of each subproduct produced by the firm. All of these surveys have been thoroughly used to estimate production functions[7].

The price information is used to construct firm specific output price indices to deflate the firm's total sales or revenue. Let us assume that the data comes from a panel of firms that report information on the number of markets (or products), total sales in each market and its price growth, i.e. $\triangle P_{ijt}/P_{ijt-1}$, where $\triangle P_{ijt} = P_{ijt} - P_{ijt-1}, i$ is the firm and j the market (product).

The firm's output price change can be obtained by a Tornqvist index, which is a weighted average of the growth in prices for individual products or materials generated by the firm. In other terms, we can write,

$$\frac{\triangle P_{it}}{P_{it-1}} = \sum_{j=1} s_{ijt} \left(\triangle P_{ijt}/P_{ijt-1} \right), \qquad t = 1, ...T, \tag{5}$$

where j indexes the number of markets served by firm i, P_{ijt} is the price in market j charged by firm i at moment t, and s_{ijt} is the share of sales declared by the firm in market $j, s_{ijt} = \frac{R_{ijt}}{R_{it}}$,and R_{ijt} and R_{it} are respectively the sales in the market j and the total sales of the firm i at time t.

The specific firm's output price level index for each period is obtained from the recursion formula

$$P_{it} = (1 + \triangle P_{it}/P_{it-1}) P_{it-1}, \qquad t = 1, ...T, \tag{7}$$

where $\triangle P_{it}/P_{it-1}$ is given in (5).

In order to implement the recursion formula in (7) we need to observe P_{i0}, but it is not observed in those surveys that report information on the output price change. The

[7] See Mairesse and Jaumandreu (2005) for a discussion about the price information of Spanish and France manufacturing panel data. See Eslava et. al (2004) for the description of the Colombian panel.

solution usually given to solve the lack of observability of the price level in the base year is to eliminate all the price differences across all firms during this year, normalizing this price level to a particular constant. For example, Eslava et al. (2004) or Jaumandreu and Mairesse (2005) set $P_{i0} = 1$ for all i at moment zero.[8]

Observe that from (7) , the price deflator at time t is given by P_{it}/P_{i0}, and when deflating the total revenue we get,

$$R_{it}^{*} = \frac{R_{it}}{(P_{it}/P_{i0})} = \frac{P_{it}Q_{it}}{(P_{it}/P_{i0})} = P_{i0}Q_{it}, \qquad t = 1, 2, ..., T; i = 1, ..., N,$$

or, in logs[9],

$$r_{it}^{*} = q_{it} + \ln P_{i0}. \tag{8}$$

It is clear that if we assume that $P_{i0} = 1$ for all i, then the unobservable fixed effect disappears. However, assuming that all firms in all industries have the same price level during the base year, i.e. there is no price dispersion during this year, seems strong assumption. A simil in international economics could be to assume that all countries have the same price level in the base year, not before not after. Moreover, the interpretation of the deflated revenue is misleading under this assumption, because two firms producing the same quantity but at different price level will be assumed to be producing to different quantities: given that $P_{i0} = 1$, then the observe deflated revenue r_{it}^{*} is interpreted as a quantity[10].

When nothing is assumed with respect to the firms' price level in the base year, then we have to account for it, considering as an unobservable fixed effect in the production

[8] Despite Eslava et al. (2004) use the EAM survey which reports the quantity and price level of each product of the firm, they use the information of rate of growth of the product price, i.e. they do not use the information of the price level to construct the price inde.

[9] Notice that $\triangle P_{ijt}/P_{ijt-1} \simeq \ln P_{ijt} - \ln P_{ijt-1}$ only if $\triangle P_{ijt}/P_{ijt-1}$ is particularly small.

[10] Ornaghi (2005) or Mairesse and Jaumandreu (2005) used the sample of Spanish manufacturing firms to address the question of the likely differences in parameter estimates of the production function when using industry or firm output price deflators. Both build the firm price index as we show in this section, but none of them take into account the problem of the price in the base period. Mairesse and Jaumandreu (2005) point out that "the price differences across firms will, by construction, be zeros in the chosen base year".

function,

$$r_{it}^* = q_{it} + p_{i0} = \beta_P l_{it}^P + \beta_T l_{it}^T + \beta_k k_{it} + \beta_m m_{it} + \omega_{it} + \ln P_{i0} + \eta_{it}$$
$$= \beta_P l_{it}^P + \beta_T l_{it}^T + \beta_k k_{it} + \beta_m m_{it} + \omega_{it} + \alpha_i + \eta_{it}. \quad (9)$$

In the next section we present a modification of OP method in order to estimate the production function parameters in the presence of the standard productivity shock and a fixed effect that is the unobserved price in the base year.

4. Production function estimation

In the first part of this section we will ignore the fixed effect in order to briefly present the OP approach and then we present the modification of these methods in order to take care of the unobservable fixed effect.

The usual identification problem that affects the estimation of equation (9) arises from the correlation between the unobserved productivity and input demand. It arises because the firm knows the value of ω_{it} when takes its inputs decisions at time t and therefore, if input demanded at time t affect the output at time t, there is a traditional omitted variables endogeneity problem: there is an unobservable variable driving some of the correlation between outputs and inputs.

Olley and Pakes (1996) propose a method to consistently estimate the parameters of the production function equation based on a set of assumptions that takes care of these endogeneity problems. There is a first assumption concerned with characterizing two types of inputs. Dynamic inputs are those whose decisions at a particular moment of time affect future profits of the firm, i.e. inputs that are characterized by high adjustment cost, such as capital. Non-dynamic input decisions have no lasting effect on future profits. For example, in their original paper they consider labor as a non-dynamic input. The second assumption refers to the timing when input decisions are taken. It is assumed that decisions on dynamic inputs for period t are taken in period $t-1$, i.e. once the value of ω_{it-1} is known. A third assumption is that ω_{it} evolves exogenously as a first order Markov process, which is considered as an scalar unobservable, i.e. only ω_{it} is unobserved. Finally, there is a strict monotonicity assumption on the investment demand function which depends on the unobservable productivity and dynamic inputs.

Under these assumptions OP developed two stage control function approach. In the first stage, investment can be expressed as a function of dynamic inputs -capital and permanent labour- and the unobservable productivity (see Fernandez and Pakes, 2008, for a similar specification). Then, given the monotonicity assumption, the unobservable productivity can be expressed as a function of investment and the dynamic inputs, $\omega_{it} = h_t\left(i_{it}, k_{it}, l_{it}^P\right)$ and substituting in the production function equation

$$\begin{aligned} q_{it} &= \beta_P l_{it}^P + \beta_T l_{it}^T + \beta_k k_{it} + \beta_m m_{it} + h\left(i_{it}, k_{it}, l_{it}^P\right) + \eta_{it} \\ &= \beta_T l_{it}^T + \beta_m m_{it} + \phi_t\left(i_{it}, k_{it}, l_{it}^P\right) + \eta_{it} \end{aligned} \tag{10}$$

Assuming that fixed-labor and materials are non-dynamic totally flexible inputs, the above equation can be estimated using a partial lineal model and the parameters β_T and β_m recovered from this first stage. Noticing that

$$\omega_{it} = \phi_t\left(i_{it}, k_{it}, l_{it}^P\right) - \beta_k k_{it} - \beta_P l_{it}^P$$

the first order Markov and the time to build assumption could be use to recover the parameters β_P, β_k in the second stage. In other terms, the first order Markov assumption implies

$$\omega_{it} = E\left(\omega_{it} | \omega_{it-1}\right) + \varepsilon_{it}$$

where the error term, ε_{it}, can be interpreted as an unexpected productivity shock. By definition, $E\left(\varepsilon_{it} g\left(\omega_{it-1}\right)\right) = 0$ for any function g measurable in $\mathcal{I}_{t-1}$, implying that this shock is orthogonal to those dynamic inputs whose demands decisions were taken in period $t-1$, i.e. $E\left(k_{it}\varepsilon_{it}\right) = E\left(l_{it}^P \varepsilon_{it}\right) = 0$ (Fernandez and Pakes, 2008).

Ackerberg et al. (2008) (ACF henceforward) argue that the parameters in the first stage of the original OP are not identified due to a multicollinearity problem. In other terms, non-dynamic inputs are functions of the unobservable productivity and hence, of the observable dynamic inputs. ACF suggest two alternatives to solve this problem. The first one is to assume that the non-dynamic input demand decisions are taken without full knowledge about ω_t in the original OP approach. That is, labor or material input decisions are done without perfect information about what the actual unobserved productivity, i.e. they are a function of a different information set than investment. The second alternative is to modify the first stage of the OP approach and estimate a nonparametric function that depends on all the inputs. In the second stage the parameters are identified using the first order Markov assumption on the unobservable productivity. In what follows, we use only the OP method introducing the ACF suggestions.

We consider that temporary labor contracts is a non-dynamic input totally flexible input and its decisions are made without perfect knowledge of the actual value of productivity. This fixed term labor contracts are usually demanded to cover unexpected demand shocks which could be assumed to be independent of actual productivity (Fernandes and Pakes, 2008; Cooper et al. 2003). On the other hand, long term or permanent labor contracts is considered to be a dynamic labor input which is subject to adjustment costs, i.e. dismissal costs. Additionally, we assume that demand decisions on materials, which is a non-dynamic input, are made without perfect knowledge of the actual value of productivity.

Having establish the basic ideas of the OP method, we return to equation (9), where the fixed effect is present and under the assumption that decisions on temporary workers and material are done without full knowledge on ω_{it}, we get

$$\begin{aligned} r_{it}^{*} &= \beta_T l_{it}^T + \beta_m m_{it} + \beta_P l_{it}^P + \beta_k k_{it} + h_t\left(i_{it}, k_{it}, l_{it}^P\right) + \alpha_i + \eta_{it} \\ &= \beta_T l_{it}^T + \beta_m m_{it} + \phi_t\left(i_{it}, k_{it}, l_{it}^P\right) + \alpha_i + \eta_{it}. \end{aligned}$$

The problem in this specification with respect to the original OP/ACF method is the existence of a second unobservable, the fixed effect α_i.

In order to estimate the above partial linear model with a fixed effect, we use Baltagi and Li's (2002) series estimator (Lee, 2007; Li and Stengos, 1996, are other alternatives) which allows us to recover the nonparametric $\phi_t(\cdot)$ function.

Taking into account that the fixed effect is due to the unknown price level in the base period, our approach is based on the differentiation with respect to the base year[11] Therefore

$$\widetilde{r}_{it}^{*} = \beta_T \widetilde{l}_{it}^{f} + \beta_m \widetilde{m}_{it} + \widetilde{\phi}_t \left(i_{it}, k_{it}, l_{it}^{P}\right) + \widetilde{\eta}_{it}.$$

where $\widetilde{x}_t = x_t - x_0$.

The first stage consist on applying Baltagi and Li's (2002) from where we can recover an estimator for β_T, β_m and ϕ_t. In the second step, the permanent labor and capital parameters can be recovered from the first-order Markov process assumption which implies that $E\left(\varepsilon_{it} k_{it}\right) = E\left(\varepsilon_{it} l_{it-1}^{P}\right) = 0.$[12].

5. Data and descriptive statistics

Our data come from the Survey on Business Strategies (Encuesta Sobre Estrategias Empresariales, ESEE) survey, an annual firm level survey of Spanish manufacturing firms sponsored by the Ministry of Industry. The data we use is an unbalanced sample of 23,463 observations that correspond to more than 2000 firms observed an average of 11 years in most industries, Table 1 shows the number of firms per year and size. The data set is particularly attractive for the empirical analysis of production functions. For example, firms are directly asked to identify the sales in different markets (up to five) and the output price growth in any of them. It contains also information about outputs (sales and stocks) and inputs (labor, intermediate inputs, investment) and the price variation of inputs. Details on industry and variable definitions can be found in Appendix A.

[11] We thank Ariel Pakes for this suggestion.

[12] The estimation procedure was programmed in Matlab-Tomlab and the standard errors were estimated through a bootstrap procedure.

Table 1. Number of firms per year and size

Year	Total	$\leq$ 200	<200
1991	1,628	920	708
1992	1,601	929	672
1993	1,428	835	593
1994	1,411	777	634
1995	1,312	719	593
1996	1,339	778	561
1997	1,538	943	595
1998	1,476	887	589
1999	1,490	921	569
2000	1,585	934	651
2001	1,266	763	503
2002	1,456	881	575
2003	1,197	708	489
2004	1,191	704	487
2005	1,692	1,028	664
2006	1,853	1,165	688
Total	23,463	13,892	9,571

Some facts about producer prices growth.—

In this section we present some empirical regularities about the dynamics of prices at the producer level. Our objective is to get more insight of the price growth at the firm level and the distance from the individual prices to the aggregate price producer index, usually used to deflate sales.

For each firm we build the average of the price changes that the firms reports in each market weighted for the share of the sales in each market as: $\frac{\triangle P_{it}}{P_{it-1}} = \sum_{j=1} s_{ijt} \left(\triangle P_{ijt}/P_{ijt-1}\right), \qquad t = 1, ...T.$, where s_{ijt} is the share of sales in market j at time t of firm i (we can obtain this value as firms reports the sales in each market) and $\triangle P_{ijt}/P_{ijt-1}$ is the percentage of price variation reported for the firm in each market. Notice that markets do not coincide with products in most cases. Usually one market include all products sold to the same retailers/firms and compete with the same competitors. On the other hand, two different markets can include the same product, which occurs, for example, when the a product is sold in the national or international market ant it is affected for different demand conditions and probably different competitors, and therefore will be priced differently. In our sample, large firms are more frequently multimarket. Half of the small firms (less than 200 workers) declare to have more than one market, while a 75% of large firms declare to have more than one market (see Table A2 of the data appendix for more details for the number of markets reported by firms of different size).

Table 2 shows the percentage of firms that increase, decrease or not variate the output prices along the period analyzed from 1991 to 2006 and the inflation rate. There are several empirical regularities to underline. First, there is a relative price stickiness in the producer prices as one third of firms did not change prices, although this percentage increased until 40-45% between 1996 to 1999, that coincide –with one period lag– with the period of lowest inflation in Spain (1997-2000). Second, producer prices are not down rigid.[13] On average the percentage of firms that moved down the prices in any year are 11%, but this percentage reached the maximum values 1992-1993 (21% and 18% respectively), the short but strong downturn at the beginning of the nineties. The third fact is that price growth is the most frequent price adjustment in all the 16 years analyzed. On average, half of the firms (52%) increased prices, but this percentage is higher in mid nineties and mid 2000. The magnitude of the price increase range from 2,1 –the median value in 1998– to 5% –the median value in 1992 and 1993–. Lastly the median values of the price decrease are in the same range: form -2% in 2002 to a -5% in 1992-1993. This figures show that when sales are deflated by any aggregate index (when positive) we are underestimated the value of sales for those firms that do not increase or even reduce the prices.

[13] Other empirical papers about prices have reported this fact, for example Dias et al (2005) that obtain that around a 45% of price changes (monthly) are reductions, while Nakamura y Steinsson (2008) obtain that this happen in one third of the cases analyzed.

Table 2. Sign and magnitude of firms' output price growth reported in the ESEE per year.

	$p_t = p_{t-1}$	$p_t < p_{t-1}$				$p_t > p_{t-1}$					
Year	%	%	Mean	Sd	Median	%	Mean	Sd	Median	PPI[1]	PCI[2]
1991	31.6%	14.5%	-6.8	5.8	-5	53.9%	5.2	3.7	5	0.2	6.4
1992	32.2%	20.5%	-6.3	5.4	-5	47.2%	4.7	3.2	5	1.5	6.8
1993	37.6%	17.7%	6.7	6.7	-4.2	44.7%	5.0	4.0	4.4	3.4	5.6
1994	33.0%	8.5%	-5.0	5.0	-3.7	58.5%	6.7	7.3	5	5.5	4.6
1995	33.4%	8.6%	-5.9	7.0	-3.2	58.0%	5.6	6.2	4	4.8	4.9
1996	40.2%	13.9%	-6.4	7.3	-4	45.9%	3.7	3.1	3	1.9	3.6
1997	45.8%	11.8%	-4.0	5.1	-2.2	42.5%	3.4	2.9	3	1.1	2.1
1998	44.9%	15.7%	-5.0	5.4	-3	39.4%	3.2	3.3	2.1	-2.0	2.3
1999	44,8%	12.3%	-5.2	5.8	-3	42.9%	3.7	4.4	3	4.2	2.4
2000	38.9%	7.9%	-4.0	5.1	-2	53.2%	4.9	5.4	3	5.2	2.5
2001	39.7%	11.1%	-4.8	5.6	-2.8	49.3%	3.5	2.7	3	-0.8	3.5
2002	31.9%	13.0%	-3.6	3.5	-2.1	55.0%	3.1	2.2	3	1.9	3.7
2003	33.4%	9.1%	-3.7	3.8	-2.3	57.6%	3.1	2.1	3	1.3	2.9
2004	31.1%	7.9%	-3.4	3.2	-2.2	61.0%	3.9	4.1	3	5.2	2.7
2005	33.2%	5.9%	-4.1	3.9	-2.6	60.9%	4.3	3.6	3.2	4.8	2.7
2006	33.9%	5.3%	-4.4	5.2	-2.3	60.8%	4.8	4.5	4	3.3	2.9
Total	36.6%	11.5%	-5.2	5.6	-3	51.9%	4.4	4.3	3		

[1]Price producer index from the Spanish Statistic Insitute

[2]Price consumer index from the Spanish Statistic Insitute (excluding non elaborated food and energy products)

Table 3 shows the relation between price change and firms' size. The first fact is that large firms change prices more often than small firms, the percentage of firms that do not change price range from 46% in the smallest firms to a 23% of the largest ones. The prices stickiness associate to size was also find in Hall et al. (2000). Several reasons would explain this fact, for example, the existence of economies of scale in collecting information to review the prices and to implement the changes[14], the fact that large firms operate in more different markets, or the degree of competence, as it is observed that firm operating in more competitive markets change prices more often[15]. The opposite regularity is founded in price reductions, large firms decrease the prices more frequently, but the average and medium values are larger. Finally, there are not significative differences in the magnitude of price increases associated with size.

Table 3. Sign and magnitude of firms' price change by firm size

	$p_t = p_{t-1}$	$p_t < p_{t-1}$				$p_t > p_{t-1}$			
Size	%	%	Mean	Sd	Median	%	Mean	Sd	Median
$\leq$ 20 workers	45.8%	5.7%	-7.2	6.5	-5	48.5%	4.6	4.0	4
21-50	41.9%	7.7%	-6.3	6.0	-4.6	50.4%	4.4	3.9	3.1
51-100	31.1%	10.6%	-5.7	6.9	-3	58.3%	4.1	4.2	3
101-200	34.6%	12.9%	-4.5	4.5	-3.3	52.4%	4.1	4.1	3
201-500	28.3%	18.6%	-4.3	4.6	-3	53.1%	4.2	4.7	3
>500	23.2%	19.7%	-5.0	5.6	-3	57.1%	4.5	5.5	3
Total	36.6%	11.4%	-5.2	5.6	-3	51.9%	4.4	4.3	3

6. Estimation results

In the following tables we present the results of estimating equation (9) when the firm's revenue is deflated by the by the industry wide price index, by the firm's specific price index but it is assumed that $P_{i0} = 1$ for all industries and finally, assuming that the price level in the base year is an unobservable fixed effect.

Overall, the Table supports the basic findings of Jaumandreu and Mairesse (2005), even when considering that the price level in the base period is unobservable. In other therms, there are no significant and systematic differences between the three approximations to the

[14] Althougt the costs of implementing price changes could include some diseconomies of scale: the cost to inform to a large number of geographically dispersed retailers. But Blinder et al. (1998) report very littel support to the fact tat large firms could be more price rigid because of bureocratic sluggishness.

[15] Carlton (1986) show that US industrial prices wer more rigid in concentrated industries.

estimation equation (9)different ways of deflating these two approximations to the revenue function. In the second place, the estimates substantially change when we correct for the fixed effect.

In the next tables we present the result of estimating first, a revenue function, using the industry price index and the firm specific price index. Both are estimated as it is commonly done in the literature the firm revenue deflected by an industry output-price index. Second, the result of deflating the firm revenue using the firm output-price index and third, we present the results of a production function that includes the unobservable firms price in the base year.

[Insert Table 4]

Table 4 summarizes the production function estimates for ten industries using the OLPS, OP and ACF methods. Columns (1) to (4) report the coefficients estimated from OLS regressions of the log of revenue on the logs of inputs. The coefficients are sensible and returns to scale, as given by $\beta_T + \beta_P + \beta_k + \beta_m$, are close to constant in all industries analyzed. The parameter for temporary employment is much lower than the parameters for permanent employment, reflecting the higher share of permanent employment in manufacturing firms. Besides, these parameters are lower than the parameter obtained using an aggregate labor input as the sum of both, as usual in papers that estimate production functions.[16] Columns 4-8 report the coefficients estimated using the standard OP estimator and, in the last four columns, we present the coefficients using the ACF method. Both of them let us to back out the unobserved productivity. Overall, what we observe in most industries when we move from OLS estimator to OP and ACF is an increase in the estimated coefficient of capital and a decrease in the estimated coefficient of materials and labor inputs, with a few exceptions in the O-P method. These changes go in the expected direction if we consider that the coefficient on the freely chosen variables labor and material inputs will be biased upwards as a positive productivity shock leads to higher labor and material

[16] The coefficients of aggregate labor of an OLS regressions reported by Jaumandreu and Doralzeski (2009) with this data base range from 0.177 to 0.335.

usage. The magnitude of the changes in these parameters is somewhat higher in ACF. The point estimates imply constant returns to scale with OP and some decreasing returns to scale, though the hypothesis of constant returns to scale cannot be rejected under typical significance levels in most industries.

[Insert Table 5]

Table 5 reports the estimated coefficient of the three methods using a firm's price deflator but assuming that the price in first period is 1. The results show in Table 5 actually display little change, this result is similar with those obtained in Jaumandreu and Mairesse (2005).

[Insert Table 6]

Table 6 reports the estimated coefficient of the three methods including the price unobservable fixed effect. In this case the sign of the bias is not clear, it could go either way as it depends on the correlation between the price a firm charges and the level of its inputs which works through the output of a firm. Although we expect that the omitted price bias might work in the opposite direction as the simultaneity bias.

Comparing the OLS estimator of the three tables (that assume strict exogeneity of the inputs) we can observe that in all industries analyzed, the estimated parameter when a fixed effect is considered are lower as are the returns to scale, this result is usually observed in those analysis that estimate the production function with a fixed effect. But when we move to our OP an ACF framework estimated with the price fixed effect, the returns to scale increase as do the estimated coefficients. The coefficient of the capital is significantly higher in all industries when the OP procedure is used and in when ACF is applied and the coefficients of the materials is lower.

CONCLUSION

In this paper we propose a modification of Olley and Pakes (1996) and Ackerberg's et al (2008) method to correct the problem that appears when deflating the firm's total revenue with an industry price index to obtain the firm's output. The use of aggregate price index introduces an omitted variable problem in the estimation of the production function as shown by Klette and Griliches (1996). The omitted unobservable variable recovers the change in the relative price of the firm's output price with respect to the industry price index.

The approach we follow here is to treat the price level in the base year as an unobservable fixed effect. We propose a modification of the first stage of the OP or the ACF approaches in order to take this unobservable fixed effect into account. The basic idea is to use Baltagi and Li (2002) semiparametric partial linear model with fixed effect estimator in the first stage.

Additionally, we relax the assumption that labor is a non-dynamic and totally variable input. Given the specific characteristics of the Spanish labor market we consider two types of labor inputs depending on the magnitude of the associated dismissal costs : Permanent (open-end) and temporary (fixed-term) employment. The first one, entails much higher dismissal costs than the second.

We apply our estimation procedure to a panel of Spanish manufacturing firms and the main results show that when we estimate a production function with two unobservable: the productivity shock and a fixed effect, the parameters obtained are lower than the obtained when we include only the productivity shock but they are significantly higher than those obtained including only one fixed effect. In general terms, the results obtained deflating the revenues by an industry index are quite similar than those obtained with partial information on prices. Moreover, the consideration of a fixed effect in a OP and ACF framework has small effect on the capital parameter and reduce the value of the flexible inputs parameters in most industries.

APPENDIX: ESEE AND VARIABLE DEFINITION

The data set used is based on the Encuesta Sobre Estrategias Empresariales (ESEE) survey, a firm-level survey of Spanish manufacturing sponsored by the Ministry of Industry. Our sample is an unbalanced panel from 1991 to 2006 representative of Spanish manufacturing firms. A first characteristic of the data set is that at the beginning of this survey in 1990, 5% of firms with up to 200 workers were sampled randomly by industry and size strata. All firms with more than 200 workers were asked to participate, and the rate of participation reached approximately 70% of the population of firms. The second characteristic of the data set is that in subsequent years the initial sample properties have been maintained. Newly created and exiting firms have been recorded in each year with the same sampling criteria as in the base year. In other term, exit attrition has been mitigated by substituting exit manufacturing firms by newly created firms following the same sampling criteria as in the base year (Jaumandreu and Doroleski, 2009). Table A1 shows the number of observations and firms by industry.

This survey includes information on capital stock, materials, production (sales and inventories) and the capacity utilization and the number of workers and the average hours. All this information makes the ESEE especially adequate to conduct our analysis.

- *Age.* The age of the firm is the difference between the current year and the year of birth declared by the firm.

- *Capital.* Capital at current replacement values K_{it} is computed recursively from an initial estimate and the data on current investments in equipment goods I_{it}. We update the value of the past stock of capital by means of the price index of investment in equipment goods p_{It} as $K_{it} = (1-\delta)\frac{p_{It}}{p_{It-1}}K_{it-1}+I_{it-1}$ where δ is an industry-specific estimate of the rate of depreciation. Capital in real terms is obtained by deflating capital at current replacement values by the price index of investment in equipment goods.

- *Investment*: value of current investments in operative capital, that is, we consider equipment goods, excluding buildings, land, and financial assets. The magnitude is deflated by the price index of investment (the equipment goods component of the index of industry prices computed and published by the Spanish Statistic Institute, INE).

- *Market dynamism.* Firms are asked to assess the current and future situation (slump, stability, or expansion) of up to 5 separate markets in which they operate. The market dynamism index is computed as a weighted average of the responses.

- *Materials*: value of intermediate consumption (including raw materials, components, energy, and services) deflated by a firm-specific price index of materials.

- *Output.* Value of produced goods and services computed as sales plus the variation of inventories deflated by a firm-specific price index of output.

- *Price variation of output.* Firm-specific price index for output. Firms are asked about the price changes they made during the year in up to 5 separate markets in which they operate. The price index is computed for each firm as a Paasche-type index of the responses and normalized by the average of its values. Missing values in the reported price variation are filling using the year industry price producer index (PPI) reported by the Spanish Institute of Statistics (INE). price variation reported

- *Permanent employment.* Number of full time plus half of part time permanent workers at December 31st.

- *Temporary employment.* Workers hired under fixed term contract at December 31st. When firms report that the proportion of fixed term contract varies during the year, this variable is the average of the temporary workers hired in each quarter.

- *Wage.* Wage cost computed as total labor cost excluding dismissal costs divided by total workers.

Table A1. Number of firm's observations by industry

	ISIC	Total	<200	>200	Average T
1. Food, drink & tobacco	D 15+16	3,284	1,904 58.0%	1,380 42%	11
2. Textile, leather, shoes	D 17+18+19	3,323	2,359 71%	964 29%	11
3. Timber & furniture.	D 20+30	1,905	1560 81.9%	345 18.1%	10
4. Paper & printing	D 21+22	1,899	1,264 66.6%	635 33.4%	10
5. Chemical products.	D 24+25	3,027	1,498 49.5%	1,529 50.5	11
6. Non metalic minerals	D 26	1,728	1,013 58.6%	715 41.4	11
7. Metal products	D27+28	3,143	2,065 65.7%	1,078 34.3	11
8. Agric. & ind. mach.	D 29	1,779	1,013 56.9%	766 43.1	11
9. Office, comp. & elec.		1,759	758 43.1%	1,001 56.9	10
10. Vehicles & acces.	D 34+35	1,616	427 74.3%	148 25.7%	11
Total		13,892	13,892 59,2%	9,571 40,8%	

Table A2. Numer of markets by size of the firm

	1 maket	2 markets	3 markets	4 markets	5markets	Total
$\leq$ 20 workers	55.9%	20.9%	13.5%	6.0%	3.8%	100%
21-50 workers	52.6%	23.4%	14.6%	4.6%	4.74%	100%
51-100 workers	37.7%	28.1%	19.2%	6.7%	8.34%	100%
101-200 workers	33.0%	34.5%	16.1%	8.3%	8.08%	100%
201-500 workers	35.1%	25.8%	20.1%	9.8%	9.32%	100%
>500 workers	28.76%	33.7%	19.7%	7.2%	10.6%	100%

Table A3. Sign and magnitude of firms' price growth per industry, 1991-2006

	$p_t = p_{t-1}$	$p_t < p_{t-1}$				$p_t > p_{t-1}$			
		%	Mean	Sd	Median	%	Mean	Sd	Median
1. Food, drink & tobacco	29.6	8.0	-5.8	6.2	-3.8	62.4	4.6	3.9	3.8
2. Textile, leather, shoes	40.8	7.1	-6.6	6.2	-5	52.1	4.1	3.6	3
3. Timber & furniture.	37.6	3.9	-5.5	4.8	-4.4	58.4	4.0	2.5	3.3
4. Paper & printing	43.0	12.0	-6.0	5.6	-4	45.1	5.6	6.6	4
5. Chemical products.	35.7	18.1	-5.1	5.8	-3	46.2	4.6	4.7	3
6. Non metalic minerals	37.5	11.7	-6.7	6.5	-5	50.8	4.3	4.2	3.1
7. Metal products	34.4	11.8	-5.9	5.9	-4.3	53.8	5.3	5.7	3.9
8. Agric. & ind. mach.	38.4	7.6	-3.9	4.1	-2.5	53.9	3.5	2.4	3
9. Office, comp. & elec.	35.9	19.4	-4.8	4.9	-3.3	44.7	3.7	3.6	3
10. Vehicles & acces.	37.3	17.8	-2.5	3.1	-2	44.9	3.2	3.6	2.65

Appendix B: Price deflator for multimarket firms.—

Firms report the price changes they made during the year in up to 5 separate markets in which they operate: $r_t^k = p_t^k - p_{t-1}^k / p_{t-1}^k$. Firms also report the share of sales in each market. If R_t represents sales of firm in period t, the deflated revenue will be

$$R_{t_0} = R_{t=\tau} \prod_{t=1}^{\tau} \left[\sum_{j=1}^{J} \frac{s_t^j}{(1 + r_t^j)} \right],$$

where R denotes firm revenues, J the number of markets, τ the number of years, s_t^j, the share of sales declared by the firm in market j and period t and r_t^j the price variation declared by the firm in market j and period t.

REFERENCES

Ackerberg, D., K. Caves and G. Frazer (2006), "Structural identification of production functions," Mimeo.

Ackerberg, D., C. L. Benkard, S. Berry, and A. Pakes (2007), "Econometric tools for analyzing market outcomes," in JamesHeckman and Edward Leamer, eds., Handbook of Econometrics, Vol. 6(1), Amsterdam: North-Holland, 2007, pp. 4171–4276.

Baltagi, B and Q. Li (2002), "On Instrumental Variable Estimation of Semiparametric Dynamic Panel Data Models," *Economics Letters*, 76, 1-9.

Bartelsman, E. J. and M. Doms (2000), "Understanding productivity: Lessons from longitudinal microdata," *Journal of Economic Literature*, 38(3), 569–594.

Blinder, Alan S., Elie R. D. Canetti, David E. Lebow, and Jeremy B. Rudd (1998), "Asking

about Prices" (New York, NY: Russell Sage Foundation, 1998).

Carlton, D. (1986), "The rigidity of prices", *American Economic Review*, 76, 637-58.

De Loecker, J. (2010), "Product differentiation, multi-product firms and estimating the impact of trade liberalization on productivity," mimeo, University of Princeton.

Dias, D., D. Maarten, E. Gautier, I. Hernando, R. Sabbatini, H. Stahl, P. Vermeulen (2005), "Price setting in the euro area: some stylised facts from individual producer price data". Working Paper European Central Bank n^o 254.

Doraszelski, U. and J. Jaumandreu (2009), R&D and productivity: Estimating endogenous productivity," mimeo, Harvard University.

Dolado, J. and Stucchi (2008), "Does temporary workers affect total factor productivity? evidence from spanish manufacturing firms," mimeo, Universidad Carlos III de Madrid.

Dolado, J., C. García-Serrano and J. F. Jimeno (2002), "Lessons from the boom of temporary jobs in Spain," *The Economic Journal*, 112, F270-F295.

Eslava, M., Haltiwanger, J., Kugler, A. and Kugler, M. (2004), "The Effects of Structural Reforms on Productivity and Profitability Enhancing Reallocation: Evidence from Colombia," *Journal of Development Economics*, 75 (2), 333-372.

Eslava, M., J. Haltiwanger, A. Kugler and M. Kugler (2010), "Factor Adjustments After Deregulation: Panel Evidence from Colombian Plants," *Review of Economics and Statistics*, 92, 378-391.

Foster, L., J. Haltiwanger, and C. Syverson (2008), "Reallocation, Firm Turnover, and Efficiency: Selection on Productivity or Profitability?," *American Economic Review* 2008, 98:1, 394–425

Hall, S., M. Walsh, A. Yates (2000), "Are UK companies' price sticky?, *Oxford Economic Papers*, 52, 425-446.

Katayama, H., S. Lu and J. Tybout (2009) "Firm-level productivity studies: Illusions and a solution," *International Journal of Industrial Organization*, 27, 403-413.

Klette, T. J. and Griliches, Z. (1996, "The inconsistency of common scale estimators when output prices are unobserved and endogenous," J*ournal of Applied Econometrics* 11, 343–361

Melitz, M. (2000), "Estimating Firm-Level Productivity in Differentiated Product Industries," mimeo, Harvard University.

Melitz and Levinsohn (2006), "Productivity in a Differentiated Products Market Equilibrium," mimeo.

Ornaghi C. (2008), "Price Deflators and the Estimation of the Production Function," *Economics Letters*, 99(1), 168-171.

Ornaghi C.(2006), "Assessing the effects of measurement errors on the estimation of a production function," J*ournal of Applied Econometrics*, 21, 879-891.

Olley, S. and Pakes, A.(1996), "The dynamics of productivity in the telecommunications equipment industry," *Econometrica* 64, 1263–97

Sánchez-Mangas, R. (2007): "La productividad en la sociedad de la información: impacto de las nuevas formas de organización del trabajo," *Moneda y Crédito*, 225, 75-96.

Santos C. (2008), "Production Functions with imperfect competition", mimeo.

Klette and Griliches 1996;

Katayama, H., S. Lu. and J. Tybout (2009) "Firm-level Productivity Studies: Illusions and a Solution," *International Journal of Industrial Organization*, 27, 403-413.

Mairesse and Jaumandreu (2005), “Using price and demand information to identify production functions,” Working paper, Universidad Carlos III de Madrid, Madrid.

Mairesse and Jaumandreu (2005), “Panel-data Estimates of the Production Function and the Revenue Function,” *Scandinavian Journal of Economics* 107(4), 651–672.

Nakamura, E. y J. Steinsson (2008), “Five Facts about prices: A reevaluation of menu cost models”. The Quarterly Journal of Economics 123 (4), 1415–1464.

Van Beveren I, (2010), "Total factor productivity estimation: a practical review,” *Journal of Economic Surveys*, forthcomming.

Van Biesebroeck, J. (2007), “Robustness of productivity estimates,” *Journal of Industrial Economics*, 55(3), 529–569

Wooldridge, W. (2009), "On estimating firm-level production functions using proxy variables to control for unobservables,” *Economic Letters,* 104(3), 112-114.

Table 1. Revenue function estimation: Revenue deflated by Industry Price Index.

	OLS				OP				ACF			
	Capital	Labor P	Labor T	Materials	Capital	Labor P	Labor T	Materials	Capital	Labor P	Labor T	Materials
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)				
1. Food, drink & tobacco	0.081 (0.020)	0.194 (0.029)	0.049 (0.012)	0.718 (0.019)	0.136 (0.024)	0.152 (0.031)	0.049 (0.014)	0.703 (0.019)	0.126 (0.035)	0.141 (0.037)	0.035 (0.017)	0.713 (0.045)
	1.041				1.040				1.015			
2. Textile, leather, shoes	0.067 (0.016)	0.239 (0.028)	0.081 (0.014)	0.578 (0.021)	0100 (0.028)	0.153 (0.042)	0.061 (0.015)	0.589 (0.018)	0.092 (0.032)	0.0.89 (0.042)	0.051 (0.020)	0.594 (0.047)
Returns to scale	0.964				0.902				0.827			
3. Timber & furniture.	0.041 ()	0.176 ()	0.050 ()	0.719 ()	0.108 (0.036)	0.172 (0.044)	0.054 (0.016)	0.685 (0.034)	0.135 (0.065)	0.105 (0.066)	0.046 (0.031)	0.483 (0.164)
Returns to scale	0.985				1.019				0.769			
4. Paper & printing	0.106 (0.023)	0.215 (0.042)	0.056 (0.013)	0.624 (0.031)	0.127 (0.029)	0.210 (0.067)	0.046 (0.012)	0.621 (0.031)	0.095 0.037	0.084 0.092	0.022 0.019	0.555 0.062
Returns to scale	1.001				1.004				0.755			
5. Chemical products.	0.116 (0.019)	0.163 (0.033)	0.033 (0.016	0.680 (0.033)	0.157 (0.038)	0.130 (0.044)	0.027 (0.015)	0.676 (0.031)	0.163 (0.041)	0.104 (0.055)	0.010 (0.018)	0.651 (0.056)
Returns to scale	0.992				0.990				0.927			
6. Non metalic minerals	0.074 (0.021)	0.252 (0.043)	0.082 (0.022)	0.640 (0.041)	0.127 (0.038)	0.201 (0.058)	0.091 (0.022)	0.614 (0.042)	0.232 (0.060)	0.142 (0.078)	0.055 (0.031)	0.537 (0.106)
Returns to scale	1.048				1.033				0.965			
7. Metal products	0.080 (0.016)	0.166 (0.023)	0.040 (0.012)	0.676 (0.020)	0.090 (0.021)	0.134 (0.035)	0.033 (0.012)	0.667 (0.019)	0.128 (0.044)	0.155 (0.065)	0.032 (0.023)	0.499 (0.131)
Returns to scale	0.962				0.923				0.814			
8. Agric. & ind. mach.	0.091 (0.024)	0.260 (0.050)	0.055 (0.017)	0.626 (0.039)	0.130 (0.010)	0.177 (0.078)	0.055 (0.017)	0.630 (0.043)	0.134 (0.046)	0.085 (0.103)	0.056 (0.030)	0.549 (0.079)
Returns to scale	1.031				0.992				0.825			
9. Office, comp. & elec.	0.023 (0.035)	0.301 (0.058)	0.085 (0.019)	0.633 (0.044)	0.029 (0.049)	0.204 (0.083)	0.074 (0.018)	0.643 (0.040)	0.004 (0.032)	0.130 (0.083)	0.005 (0.022)	0.545 (0.068)
Returns to scale	1.041				0.950				0.684			
10. Vehicles & acces.	0.078 (0.027)	0.201 (0.032)	0.085 (0.020)	0.608 (0.048)	0.113 (0.044)	0.211 (0.061)	0.089 (0.020)	0.607 (0.053)	0.120 (0.058)	0.219 (0.093)	0.034 (0.022)	0.452 (0.149)

Table 2. Production function estimation: Revenue deflated with firm's output price index.

	OLS				OP				ACF			
	Capital	Labor P	Labor T	Materials	Capital	Labor P	Labor T	Materials	Capital	Labor P	Labor T	Materials
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)				
1. Food, drink & tobacco	0.072	0.154	0.029	0.746	0.112	0.120	0.033	0.734	0.054	0.122	0.030	0.767
	(0.018)	(0.031)	(0.014)	(0.021)	(0.024)	(0.035)	(0.014)	(0.021)	0.034	0.041	0.021	0.039
Returns to scale	1.001				0.999				0.972			
2. Textile, leather, shoes	0.072	0.229	0.068	0.572	0.125	0.141	0.047	0.586	0.091	0.084	0.046	0.582
	(0.018)	(0.027)	(0.017)	(0.022)	(0.027)	(0.046)	(0.016)	(0.020)	0.031	0.042	0.023	0.040
Returns to scale	0.941				0.899				0.803			
3. Timber & furniture.	0.058	0.150	0.034	0.735	0.123	0.143	0.039	0.706	0.144	0.109	0.043	0.487
	(0.025)	(0.034)	(0.022)	(0.037)	(0.037)	(0.043)	(0.022)	(0.040)	(0.066)	(0.069)	0.033	0.165
Returns to scale	0.977				1.011				0.783			
4. Paper & printing	0.158	0.176	0.056	0.607	0.175	0.183	0.046	0.601	0.146	0.140	0.030	0.578
	(0.027)	(0.058)	(0.017)	(0.037)	(0.034)	(0.078)	(0.017)	(0.038)	0.043	0.085	0.022	0.070
Returns to scale	0.998				1.004				0.893			
5. Chemical products.	0.128	0.169	0.040	0.693	0.164	0.154	0.036	0.687	0.180	0.130	0.005	0.666
	(0.025)	(0.038)	(0.018	(0.038)	(0.046)	(0.050)	(0.016)	(0.037)	(0.049)	(0.059)	(0.021)	(0.064)
Returns to scale	1.031				1.041				0.981			
6. Non metalic minerals	0.092	0.257	0.082	0.620	0.097	0.220	0.096	0.597	0.248	0.145	0.049	0.522
	(0.023)	(0.041)	(0.022)	(0.029)	(0.043)	(0.050)	(0.021)	(0.027)	(0.058)	(0.078)	(0.028)	(0.092)
Returns to scale	1.051				1.011				0.964			
7. Metal products	0.098	0.142	0.039	0.692	0.116	0.114	0.031	0.681	0.163	0.141	0.051	0.491
	(0.018)	(0.027)	(0.015)	(0.022)	(0.023)	(0.038)	(0.016)	(0.023)	(0.050)	(0.076)	(0.026)	(0.129)
Returns to scale	0.971				0.942				0.846			
8. Agric. & ind. mach.	0.063	0.275	0.060	0.637	0.087	0.227	0.059	0.635	0.152	0.410	0.057	0.624
	(0.022)	(0.049)	(0.020)	(0.044)	(0.039)	(0.080)	(0.019)	(0.044)	(0.046)	(0.126)	(0.033)	(0.091)
Returns to scale	1.036				1.008				1.243			
9. Office, comp. & elec.	0.036	0.283	0.094	0.655	0.070	0.202	0.085	0.668	0.021	0.089	0.011	0.594
	(0.038)	(0.073)	(0.024)	(0.050)	(0.059)	(0.102)	(0.021)	(0.046)	(0.042)	(0.088)	(0.028)	(0.081)
Returns to scale	1.067				1.025				0.716			
10. Vehicles & acces.	0.067	0.200	0.094	0.605	0.061	0.249	0.089	0.601	0.073	0.213	0.030	0.420
	(0.039)	(0.041)	(0.023)	(0.068)	(0.079)	(0.074)	(0.025)	(0.069)	(0.070)	(0.100)	(0.025)	(0.176)

Table 3. Production function estimation with fixed effects: Revenue deflated with firm's output price index. estimation with fixed effect

	OLS				O-P				ACF			
	Capital	Labor P	Labor T	Materials	Capital	Labor P	Labor T	Materials	Capital	Labor P	Labor T	Materials
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)				
1. Food, drink & tobacco	0.025	0.147	0.072	0.501	0.099	0.171	0.066	0.487	0.077	0.105	0.071	0.578
	(0.036)	(0.054)	(0.020)	(0.074)	(0.035)	(0.057)	(0.020)	(0.070)	(0.039)	(0.059)	(0.023)	(0.066)
Returns to scale	0.745				0.822				0.831			
2. Textile, leather, shoes	0.097	0.176	0.058	0.562	0.112	0.178	0.072	0.544	0.122	0.145	0.066	0.538
	(0.033)	(0.045)	(0.017)	(0.042)	(0.038)	(0.047)	(0.017)	(0.046)	(0.032)	(0.042)	(0.019)	(0.049)
Returns to scale	0.893				0.905				0.870			
3. Timber & furniture.	0.023	0.169	0.121	0.607	0.125	0.266	0.116	0.585	0.260	0.156	0.088	0.447
	(0.023)	(0.048)	(0.019)	(0.067)	(0.055)	(0.066)	(0.018)	(0.066)	(0.076)	(0.069)	(0.033)	(0.145)
Returns to scale	0.920				1.092				0.950			
4. Paper & printing	0.059	0.148	0.042	0.637	0.111	0.169	0.037	0.654	0.079	0.139	0.025	0.611
	(0.031)	(0.069)	(0.019)	(0.075)	(0.046)	(0.099)	(0.018)	(0.080)	(0.034)	(0.067)	(0.020)	(0.069)
Returns to scale	0.887				0.971				0.854			
5. Chemical products.	0.091	0.143	0.054	0.608	0.146	0.272	0.041	0.587	0.153	0.064	0.014	0.613
	(0.030)	(0.049)	(0.018)	(0.056)	(0.050)	(0.090)	(0.017)	(0.051)	(0.041)	(0.063)	(0.021)	(0.052)
Returns to scale	0.896				1.045				0.844			
6. Non metalic minerals		0.329	0.058	0.488	0.085	0.302	0.058	0.491	0.140	0.264	0.022	0.455
	(0.041)	(0.084)	(0.028)	(0.118)	(0.066)	(0.076)	(0.025)	(0.127)	(0.048)	(0.092)	(0.035)	(0.106)
Returns to scale	0.875				0.936				0.881			
7. Metal products	0.043	0.222	0.061	0.629	0.111	0.283	0.071	0.563	0.099	0.371	0.111	0.410
	(0.029)	(0.059)	(0.018)	(0.051)	(0.035)	(0.054)	(0.017)	(0.051)	(0.060)	(0.080)	(0.030)	(0.142)
Returns to scale	0.955				1.028				0.990			
8. Agric. & ind. mach.	0.015	0.265	0.046	0.581	0.063	0.342	0.038	0.552	0.184	0.374	0.015	0.533
	(0.022)	(0.058)	(0.018)	(0.052)	(0.051)	(0.075)	(0.018)	(0.051)	(0.046)	(0.110)	(0.025)	(0.075)
Returns to scale	0.908				0.994				1.106			
9. Office, comp. & elec.	0.043	0.180	0.060	0.576	0.136	0.208	0.065	0.538	0.054	0.300	0.041	0.549
	(0.039)	(0.072)	(0.018)	(0.063)	(0.043)	(0.091)	(0.014)	(0.053)	(0.040)	(0.082)	(0.023)	(0.071)
Returns to scale	0.859				0.947				0.944			
10. Vehicles & acces.	0.099	0.173	0.066	0.539	0.139	0.276	0.061	0.531	0.096	0.215	0.056	0.360
	(0.041)	(0.071)	(0.026)	(0.090)	(0.077)	(0.087)	(0.022)	(0.091)	(0.065)	(0.107)	(0.024)	(0.159)