# Using production function estimates to measure the impact of outsourcing: Evidence from manufacturing firms*

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**Abstract**

This paper is aimed at estimating a firm-level production function in which the possibility of production subcontracting is structurally considered. I assume a nested production function where, besides traditional inputs (labor and capital), an intermediate input is also needed. This intermediate input can be produced within the firm (using labor and materials) or can be purchased. Preliminary results are good in terms of estimated elasticities for traditional inputs.

Key words: Production function estimates, production subcontracting
JEL Classification: D24, D21, L60

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## 1. Introduction

The "outsourcing" or contracting out of manufacturing activities and business services has been a growing characteristic of manufacturing firms during the eighties and nineties. The systematic modification of the boundaries of the firm must be seen as part of the organizational innovation process, carried out in the search for increasing flexibility and efficiency.

McMillan (1995) enumerates the main changes introduced by the U.S. firms in their supplier relationships. One of these changes is the increment in the production subcontracting. On the other hand, Abraham and Taylor (1996) show the increment in the contracting out of business services in U.S. industry.

The "outsourcing" should be included in the general context of the "make" or "buy" decision. Just as it exposed by Coase (1937), this type of decisions determines the boundaries of the firm.

Since Williamson (1985) and Grossman and Hart (1986), a body of literature has focused on the role of transaction costs, asset specificity, and incomplete contracts in the "make" or "buy" decision. However, most of this literature has treated the industry environment as given and has focused on the relation between a single producer and a potential supplier (see, among others, Kamien, Li and Samet, 1989; Lewis and Sappington, 1991; and Spiegel, 1993). Recently, Grossman and Helpman (2002) have developed a model in which integration and "outsourcing" are treated as equilibrium phenomena (taking into account the interdependence among the firms' choices). These authors focus on the trade-off between the costs of running a larger and less specialized firm and the costs from search frictions and imperfect contracting.

Literature on "outsourcing" reveals numerous explanations for this phenomenon (see, among others, Abraham, 1990; Abraham and Taylor, 1996; Holmes, 1986; and McMillan, 1995). This practice comes explained by cost reduction by firms. At least three general considerations may affect a firm's decision to contract out in order to minimize costs. Firstly, the structure and stability of product markets (i.e., uncertain or irregular product demand

because of cyclical or seasonal variations, etc.). Secondly, the existence of economies of scale in the production or in the provision of the service (i.e., technical characteristics and fixed capital costs of the production technology, etc.). And finally, the characteristics of the labor process organization (i.e., subcontracting to minimize and control labor costs, subcontracting to retain flexibility with respect to variable capital, etc.)

Summing up, both theoretical models and hypothesis reveal minimizing of costs as the main explanation for "outsourcing". The rationale for "outsourcing" a task comes from the fact that the cost of performing it inside the firm has become at least as high as contracting it out.

The effect of "outsourcing" on the firm-level production is not clear *apriori*. On the one hand, the action of "outsourcing" one task will imply substitution of intermediate consumption for labor for approximately the same value, raising a discrete change in the firm-level production function. On the other hand, as it was mentioned, this practice can be considered as an organizational innovation. Therefore, production subcontracting can be an important variable explaining production shifts.

With respect to empirical literature on this topic, Abraham and Taylor (1996) report empirical findings of employers' motives for contracting out business services in U.S. industry. These authors find empirical evidence supporting the influence of wage savings, economies of scale and smoothening production cycles on the contracting out decision. The main body of empirical literature has focused on the relationship between "outsourcing" and productivity growth[1]. Siegel and Griliches (1992), in assessing whether outsourcing leads to an overstatement of manufacturing productivity growth, find a weak correlation during the eighties in the use of selected purchased services. On the other hand, Ten Raa and Wolff (2001) find a positive association between the rate of outsourcing and productivity growth in the goods' sector.

The aim of this paper is to introduce and estimate a simple theoretical framework which specifies a production function considering the possibility of production subcontracting.

[1] See Heshmati (2003) for a detailed survey of recent contributions to the relationship between outsourcing, efficiency and productivity growth in manufacturing and services.

Therefore, a nested production function approach is used. In addition to traditional inputs (labor and capital), I assume a production function in which it is necessary using an intermediate input ($I$). This intermediate input can be produced internally by the firm (using labor and intermediate consumptions) or can be subcontracted, with some substitution (a parameter of technical possibilities of "outsourcing" is introduced).

The rest of the paper is organized as follows. Section 2 introduces the theoretical framework. Section 3 details the econometric equation to be estimated and the estimation method. Section 4 introduces the data set and the variables, and describes the main facts about production subcontracting for the Spanish manufacturing firms during the nineties. Section 5 presents the empirical results. Section 6 concludes and presents the scope for further research. Appendix A gives details on the variables employed. Appendix B reports the details on the industry breakdown used to define industry dummies.

## 2. Theoretical framework

Consider that the production function takes the form:

$$Y = AF(K, L, I) \tag{1}$$

For simplicity, I assume a Cobb-Douglas production function:

$$Y = AK^{\delta}L^{\alpha}I^{\rho} \tag{2}$$

A is an index of Hicks-neutral technical progress. K represents the capital stock and L the labour input. Given technology, it is necessary to use an input $I$. This input can be produced within the firm ($I_f$) or can also be obtained combining in-house production and outside sources (input $I$ can be purchased, $I_s$). The procurement of $I$ can be expressed

$$I = I_f \; e^{\lambda I_s} \tag{3}$$

Finally, production within the firm of input $I$ can be written as:

$$I_f = I_f(L, M) = L_f^{\gamma} M^{1-\gamma} \tag{4}$$

Where $L_f$ represents labour input and $M$ row materials plus external services (intermediate consumptions excluding subcontracted purchases). For simplicity, the capital input ($K$) is not included in the internal production of $I$.

The production of $I_f$ responds to the following cost minimization problem:

$$\begin{cases} Min\ wL_f + p_M M \\ s.t.\ L_f^{\gamma} M^{1-\gamma} = \overline{I}_f \end{cases} \tag{5}$$

solving this problem I get:

$$\frac{L_f}{M} = \frac{\gamma}{1-\gamma} \frac{p_M}{w} \tag{6}$$

Substituting (3), (4) and (6) in (2), I can write:

$$Y = AK^{\delta} L^{\alpha} M^{\rho} \left( \frac{\gamma}{1-\gamma} \right)^{\phi_1} \left( \frac{p_M}{w} \right)^{\phi_1} e^{\phi_2 I_s} \tag{7}$$

where

$$\begin{cases} \phi_1 = \gamma\rho \\ \phi_2 = \lambda\rho \end{cases} \tag{8}$$

Note that the total labour used among both production processes is $L_t = L + L_f$ ($L$ and $L_f$ are not observable)

Then, I can write:

$$L^{\alpha} = (L_t - L_f)^{\alpha} = L_t^{\alpha} \left( 1 - \frac{L_f}{L_t} \right)^{\alpha}$$

and substituting on (7) I obtain:

$$Y = AK^{\delta} L_t^{\alpha} \left( 1 - \frac{L_f}{L_t} \right)^{\alpha} M^{\rho} \left( \frac{\gamma}{1-\gamma} \right)^{\phi_1} \left( \frac{p_M}{w} \right)^{\phi_1} e^{\phi_2 I_s} \tag{9}$$

## 3. Econometric model

***Empirical specification***

Taking logarithms in expression (9) I can write:

$$\begin{aligned}\log Y = \log A + \delta \log K + \alpha \log L_t + \alpha \log\left(1 - \tfrac{L_f}{L_t}\right) + \rho \log M + \phi_1 \log\left(\tfrac{\gamma}{1-\gamma}\right) \\ + \phi_1 \log\left(\tfrac{p_M}{w}\right) + \phi_2 I_s\end{aligned} \tag{10}$$

Again, $L_f$ is not observable. But note that, $\alpha \log\left(1 - \frac{L_f}{L_t}\right) \approx -\alpha \frac{L_f}{L_t} = -\alpha \frac{\frac{L_f}{M}}{\frac{L_t}{M}} = -\alpha \frac{\gamma}{1-\gamma} \frac{p_M M}{w L_t}$. Substituting on (10):

$$\begin{aligned}\log Y = \log A + \delta \log K + \alpha \log L_t + \rho \log M + \phi_1 \log\left(\tfrac{\gamma}{1-\gamma}\right) + \phi_1 \log\left(\tfrac{p_M}{w}\right) \\ + \phi_2 I_s + \phi_3 \tfrac{p_M M}{w L_t}\end{aligned} \tag{11}$$

where

$$\phi_3 = -\frac{\alpha\gamma}{1-\gamma} \tag{12}$$

Using lowercase letters to represent log differences, the relevant equation to be estimated maybe expressed as follows:

$$y = a + \delta k + \alpha l_t + \rho m + \phi_1 rpr + \phi_2 sub + \phi_3 csh + \varphi cu + D\zeta + u \tag{13}$$

$$\begin{aligned}\phi_1 &= \gamma\rho \\ \phi_2 &= \lambda\rho \\ \phi_3 &= -\frac{\alpha\gamma}{1-\gamma}\end{aligned}$$

Where $y$, $k$, $l_t$ and $m$ are, respectively, the rates of growth of output, capital, labor, intermediate consumptions (excluding subcontracted purchases). The variable $rpr$ is the rate of growth of price ratio $\left(\frac{p_M}{w}\right)$, the variable $sub$ is the variable production subcontracting

$(I_s)$ in differences, and the variable $csh$ is the ratio $\frac{p_M M}{wL_t}$ in differences. Estimation of a production function makes it important to control for input utilization, and hence the inclusion of the variable capacity utilization $(cu)$. $D$ represents the set of dummy variables included.

***Estimation method***

I obtain an equation (Expression 13) with nonlinear restrictions in the parameters. Therefore, Expression (13) is estimated using non-linear GMM estimation:

$$\min_{\theta} \left[\frac{1}{N}\sum_{i=1}^{N} Z_i^{'} u_i\right]^{'} \Lambda \left[\frac{1}{N}\sum_{i=1}^{N} Z_i^{'} u_i\right] \tag{14}$$

where $Z_i$ is the matrix of instruments and $\theta = (\delta, \alpha, \rho, \gamma, \lambda, \varphi, \zeta)$. A preliminary estimation of $\theta$ can be obtained with

$$\Lambda = \left(\frac{1}{N}\sum_{i=1}^{N} Z_i^{'} Z_i\right)^{-1} \tag{15}$$

A robust variance estimate of the parameters can be obtained by employing the formula $\mathrm{Var}(\theta) = \left(\Gamma^{'}\Lambda\Gamma\right)^{-1}\Gamma^{'}\Lambda E\left(Z_i^{'}u_i u_i^{'}Z_i\right)\Lambda\Gamma\left(\Gamma^{'}\Lambda\Gamma\right)^{-1}$, where $\Gamma = E\left(\frac{\partial\left(Z_i^{'}u_i\right)}{\partial\theta}\right)$ is estimable using $\frac{1}{N}\sum_{i=1}^{N}\frac{\partial\left(Z_i^{'}\hat{u}_i\right)}{\partial\theta}$ and $E\left(Z_i^{'}u_i u_i^{'}Z_i\right)$ is estimable using $\frac{1}{N}\sum_{i=1}^{N} Z_i^{'}\hat{u}_i\hat{u}_i^{'}Z_i$.

In practice, Expression 13 can be "concentrated out" for the estimation of parameters which enter linearly, and the non-linear search is over $\alpha, \rho, \gamma$ and $\lambda$.

## 4. Data, variables and description

The data used correspond to the official survey "Encuesta sobre estrategias empresariales", ESEE, (Survey on Firm Strategies). ESEE is an unbalanced panel survey of Spanish manufacturing firms with 10 or more workers, starting in 1990 and sponsored by the Ministry of Industry. At the beginning of the survey, all firms with more than 200 workers were requested to participate, while a representative sample of 5% of the firms with fewer than 200 workers was randomly selected. The final sample employed depends on the data

availability and the number of consecutive time observations required. For the description analysis showed in this section, the sample used includes a total number of 2831 firms during the period 1990-99.

ESEE provides detailed information on firms' output, capital, labor (measured through total hours of work) and intermediate consumptions. Moreover, the data provide information about production subcontracting. Specifically, I have information indicating whether the firm subcontracts production and information about subcontracted purchases. A unique feature of this data set is the availability of information on the changes in the prices set by the firm, and on the changes in the prices that the firm pays for its non-labor inputs. Detailed definitions of all employed variables can be found in Appendix A.

In what follows, I present the main facts about production subcontracting from the Spanish manufacturing firms during the nineties[2]. Table 1 shows the percentage of firms that subcontract production during the period 1990-99. Big firms are more likely to subcontract, and this gap does not decrease during the period. Moreover, it seems that a positive relation between the decision of production subcontracting and the Spanish industrial cycle during the nineties exists. The period analyzed coincides with a complete industrial cycle. In 1991, manufacturing experienced an important downturn. Recovery starts in 1994 with only a minor halt in 1996 and in 1999. Percentage of firms that subcontract production reflects a similar evolution in the figures reported in Table 1. With respect to the differences between industries[3], Table 2 shows that firms from heavy industries (i.e. Industrial and agricultural machinery, Office and data processing machinery, Other transport equipment, etc.) are more likely to subcontract than firms from light industries (i.e., Beverages, Food and tobacco, Meat and preserved meat, etc.).

While studying the intensity in production subcontracting, I use the ratio between subcontracted purchases and (total) intermediate consumptions. I restrict the attention to those firms that subcontract production. This ratio is 18.1% for firms with less than 200 workers

[2]See López (2002) for a more detailed description of production subcontracting and externalization of services from the Spanish manufacturing firms during the nineties.

[3]Industry level is defined in Appendix B.

and 14.3% for firms with more than 200 workers (see Table 3). We find out that small firms are more intensive in production subcontracting than big ones. This result maybe shown in the bidirectional relation between "outsourcing" and firm's structure, specifically between "outsourcing" and firm's size (measured by the number of workers). The higher the intensity in subcontracting, the higher the substitution of intermediate consumptions for labor.

Table 4 shows that industries with a higher intensity in production subcontracting are Industrial and agricultural machinery; Vehicles, cars and motors; Other transport equipment; Beverages; and Textiles and clothing. On the other hand, industries with a lower intensity in production subcontracting are Ferrous and non-ferrous metals; Non-metallic minerals; Chemical products; Meat and preserved meat; and Rubber and plastic products. The relation between the intensity of production subcontracting and the industrial cycle is more complex, and its study lies outside of the scope of this paper.[4]

## 5. Empirical results

Table 5 presents preliminary estimates using non-linear GMM. Estimation of the production function is carried out taking capital as predetermined, and labor, non-subcontracted intermediate consumptions, subcontracted purchases, prices and cost of variable inputs as endogenous variables.

Labor, non-subcontracted intermediate consumptions, subcontracted purchases and cost of variable inputs are instrumented with their levels lagged three periods at each cross-section. Capital is instrumented using the capital growth rate at t-1. Finally, prices ($p_M$ and $w$) are instrumented with their industry levels[5].

Equation includes eighteen industry dummies, yearly time dummies and size dummies. These industry, time and size dummies are included with their coefficients constrained to add up to zero. I include a dummy indicating if the firm has been created during the period,

[4] See Delgado, Jaumandreu and Martín-Marcos (1999), and López (2002) for evidence on the relationship between "outsourcing" and the Spanish industrial cycle during the nineties.

[5] Industry level is defined in Appendix B.

and one dummy indicating if the firm is going to exit during the period. Moreover, to control for discrete changes, dummies indicating merger/acquisition or scission are included.

Results are good in terms of estimated elasticities for traditional inputs ($k$, $l$, $m$): the elasticities of capital, labor and intermediate consumptions (excluding subcontracted purchases) are 0.14, 0.39 and 0.48, respectively. However, the parameter of interest $\gamma$ is not well estimated (obtaining a negative value). Current research is focused on solving this problem.

(To be completed)

## 6. Conclusions and remarks for further research

"Outsourcing" is an increasingly used strategy for production organization, carried out in the search for increasing flexibility and efficiency. This paper has addressed a preliminary look at the specification and estimation of a production function in which the possibility of production subcontracting is structurally considered. I assume a nested production function where, besides traditional inputs (labor and capital), an intermediate input is also needed. This intermediate input can be produced within the firm (using labor and materials) or can be purchased. Using non-linear GMM estimation, I obtain good results in terms of estimated elasticities for traditional inputs: the elasticities of capital, labor and intermediate consumptions (excluding subcontracted purchases) are 0.14, 0.39 and 0.48, respectively.

(To be completed)

## Appendix A: Variable definitions

*Capacity utilization:* Yearly average rate of capacity utilization reported by the firm.

*Capital stock:* Capital at current replacement values is computed recursively from an initial estimate and the data on firms' investments in equipment goods (but not buildings or financial assets), actualized by means of a price index of capital goods, and using sectorial estimates of the rates of depreciation. Real capital is then obtained by deflating the current replacement values. Details on this variable can be found in Martín-Marcos and Suárez (1997).

*Entrant firm:* Dummy variable that takes the value 1 when the firm has been created during the period.

*Exiting firms:* Dummy variable that takes the value 1 when the firm is going to exit during the period (stop activity or leave manufacturing).

*Hours of work:* Total normal hours of work plus overtime minus lost hours, computed multiplying hours per worker by the number of workers.

*Hours per worker:* Normal hours of work plus overtime minus lost hours per worker.

*Industry dummies:* Eighteen industry dummies (See Appendix B).

*Intermediate consumption:* Sum of purchases of materials and external services minus the variation of intermediate inventories. Nominal intermediate consumption is deflated by the firm's specific price index of intermediate consumption.

*Merger and acquisition:* Dummy variable that takes the value 1 in the years subsequent to a merger or acquisition.

*Output:* Goods and services production. Sales plus the variation of inventories deflated by the firm's output price index.

*Price:* Paasche-type price index computed starting from the percentage price changes that the firm reports to have made in the markets in which it operates.

*Price of intermediate consumption:* Paasche-type price index computed starting from the percentage variations in the prices of purchased materials, energy and services reported by the firms.

*Scission:* Dummy variable that takes the value 1 in the years subsequent to a scission.

*Size:* Two size dummies (less or equal than 200 workers; and more than 200 workers).

*Subcontracted purchases:* Purchases of final products or customized components. Nominal subcontracted purchases are deflated by the firm's specific price index of intermediate consumption.

*Wage:* Firm's hourly wage rate (total labour cost divided by effective total hours of work).

*Workers:* Approximation to the average number of workers during the year.

**Appendix B: Industry definitions**

| NACE Code (3-digit) | Industry |
|---|---|
| 221 to 224 | Ferrous and non-ferrous metals |
| 240 to 249 | Non-metallic mineral products |
| 251 to 255 | Chemical products |
| 311 to 319 | Metal products |
| 321 to 329 | Industrial and agricultural machinery |
| 330, 391 to 399 | Office and data processing machinery |
| 341 to 347, 351 to 355 | Electrical goods |
| 361 to 363 | Motor vehicles |
| 371, 372, 381 to 389 | Other transport equipment |
| 413 | Meats, meat preparation |
| 411, 412, 414 to 423, 429 | Food products and tobacco |
| 424 to 428 | Beverages |
| 431 to 439, 453 to 456 | Textiles and clothing |
| 441, 442, 451, 452 | Leather, leather and skin products |
| 461 to 468 | Timber, wooden products |
| 471 to 475 | Paper and printing products |
| 481, 482 | Rubber and plastic products |
| 491 to 495 | Other manufacturing products |

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Table 1. Percentage of firms that subcontract production
Total manufacturing (by year)

| | $\leq$ 200 workers | $>$ 200 workers |
|---|---|---|
| 1990 | 30.18 | 47.97 |
| 1991 | 40.32 | 57.80 |
| 1992 | 39.13 | 53.04 |
| 1993 | 37.31 | 52.83 |
| 1994 | 35.86 | 52.54 |
| 1995 | 36.95 | 52.49 |
| 1996 | 37.12 | 54.27 |
| 1997 | 40.76 | 54.73 |
| 1998 | 43.41 | 56.24 |
| 1999 | 37.86 | 56.88 |
| | | |
| Total[1] | 38.68 | 53.12 |

[1]Average of period 1990-99

Table 2. Percentage of firms that subcontract production[1]
Total manufacturing (by industry)

| | $\leq$ 200 workers | $>$ 200 workers |
|---|---|---|
| Ferrous and non ferrous metals | 35.40 | 22.22 |
| Non-metallic minerals | 24.04 | 34.61 |
| Chemical products | 24.14 | 52.00 |
| Metal products | 45.46 | 59.91 |
| Industrial and agricultural machinery | 64.38 | 65.95 |
| Office and data processing machinery | 60.58 | 56.99 |
| Electrical and electronic goods | 53.92 | 63.57 |
| Vehicles, cars and motors | 47.67 | 58.83 |
| Other transport equipment | 46.89 | 70.91 |
| Meat and preserved meat | 10.22 | 32.00 |
| Food and tobacco | 14.34 | 43.46 |
| Beverages | 9.23 | 26.32 |
| Textiles and clothing | 44.47 | 64.11 |
| Leather and shoes | 41.32 | 59.26 |
| Timber and furniture | 32.58 | 39.29 |
| Paper and printing products | 48.28 | 52.47 |
| Rubber and plastic products | 42.61 | 60.61 |
| Other manufacturing products | 57.01 | 75.29 |
| | | |
| Total manufacturing | 38.68 | 53.12 |

[1]Average of period 1990-99

Table 3. Subcontracted purchases over Intermediate consumptions (%)
Firms that subcontract production (by year)

| | $\leq$ 200 workers | $>$ 200 workers |
|---|---|---|
| 1990 | 19.1 | 16.1 |
| 1991 | 17.8 | 10.9 |
| 1992 | 19.6 | 12.4 |
| 1993 | 18.2 | 13.2 |
| 1994 | 17.7 | 13.7 |
| 1995 | 17.0 | 13.9 |
| 1996 | 19.0 | 14.3 |
| 1997 | 18.2 | 14.4 |
| 1998 | 17.8 | 14.7 |
| 1999 | 19.1 | 14.9 |
| Total[1] | 18.1 | 14.3 |

[1]Average of period 1990-99

Table 4. Subcontracted purchases over Intermediate consumptions[1] (%)
Firms that subcontract production (by industry)

| | $\leq$ 200 workers | $>$ 200 workers |
|---|---|---|
| Ferrous and non ferrous metals | 7.5 | 10.7 |
| Non-metallic minerals | 13.2 | 9.9 |
| Chemical products | 7.2 | 6.2 |
| Metal products | 17.6 | 14.5 |
| Industrial and agricultural machinery | 23.9 | 19.3 |
| Office and data processing machinery | 19.8 | 13.1 |
| Electrical and electronic goods | 17.6 | 17.5 |
| Vehicles, cars and motors | 20.7 | 19.4 |
| Other transport equipment | 20.7 | 22.0 |
| Meat and preserved meat | 6.8 | 6.6 |
| Food and tobacco | 13.6 | 9.7 |
| Beverages | 30.5 | 18.0 |
| Textiles and clothing | 21.0 | 16.7 |
| Leather and shoes | 17.6 | 9.3 |
| Timber and furniture | 19.6 | 14.0 |
| Paper and printing products | 21.8 | 11.9 |
| Rubber and plastic products | 12.6 | 12.9 |
| Other manufacturing products | 13.5 | 15.2 |
| Total manufacturing | 18.1 | 14.3 |

[1]Average of period 1990-99

Table 5. Production function estimates
Non-linear GMM estimation

| Sample period: 1993-1999<br>N$^o$ of firms: 1558 | |
|---|---|
| Independent variables | |
| Constant | 0.02(0.01) |
| k | 0.14(0.08) |
| $l_t$ | 0.39(0.12) |
| m | 0.48(0.09) |
| cu | 0.06(0.02) |
| Industry dummies | Included |
| Time dummies | Included |
| Size dummy | Included |
| $\lambda$ | 0.01(0.001) |
| $\gamma$ | -0.05(0.03) |
| Function value | 24.04 |

First step standard errors, robust to arbitrary autocorrelation over time and heteroskedasticity across firms.