Firm Level Productivity under Imperfect Competition in Output and Labor Markets

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Abstract

This article examines the role of the interaction between product market and labor market imperfections in determining total factor productivity growth (TFPG). Embedding Dobbelaere and Mairesse's (2009) generalization of Hall's (1990) approach, allowing for the possibility that wages are determined according to an efficient bargaining process between employers and employees, we correct estimated TFPG for possible biases arising from labor market imperfections. Our analysis contributes to the literature in a number of ways. First, we propose a new empirical measure of TFPG which takes into account possible biases coming from imperfect competition on both labor and output markets, whereas Dobbelaere and Mairesse (2009) focus on the decomposition of the Solow residual. Second, in contrast to most of the literature following Hall's approach, we estimate market power including the user cost of capital stock. Third, we measure the sensitivity of TFPG to an alternative specification of competition based on relative profits. Using a large Dutch firm-level panel database over the period 1989-2005, we find that workers' unions power, and in general rigidities of the labor market, affect firms' marginal cost, and, consequently, the markups. Moreover, taking into account variable returns to scale and imperfect competition in the output market translate into increased TFPG, while accounting for labor market bargaining power leads to lower TFPG. Next, the investigation of our empirical relationship between the price-cost margin and an alternative specification of imperfect competition of the output market (profit elasticity) as a sensitivity analysis of the TFPG shows that adding more structure to the competition measure does not affect the level of productivity change.

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1 Introduction

The analysis and measurement of productivity performance has attracted a great deal of attention ever since Solow (1957) decomposed the growth in output into the growth of inputs and a residual-based productivity term.

A fascinating approach followed in the literature is to correct the Solow residual for departures from perfect competition, estimating mark-ups over marginal cost, scale elasticities and shadow prices, and modifying the formula for the residual (Hall, 1986, 1988, and 1990). Hall's approach starts from the result that the Solow residual is no longer equal to the rate of technical change when there is imperfect competition in product markets, but that the two are related by an equation which now includes a component involving the markup of price over marginal cost.

The analysis of imperfect competition in labor markets, led by Dickens and Katz (1987), has also received great attention and given rise to a large literature in labor economics, but this literature has typically remained separate from that on imperfect competition in product markets. Only a few studies (Bughin, 1996; Crépon *et al.*, 2002; Dobbelaere, 2004; Dobbelaere and Mairesse, 2009) have considered the possibility of imperfections in both product and factor markets, by taking into account that wages are no longer exogenous.

Dobbelaere and Mairesse (2009), following Crépon *et al.* (2002), assume that workers have a degree of market power when negotiating with the firm over wages and employment. Under this conjecture, they show that product and labor market imperfections generate a wedge between factor elasticities in the production function and their corresponding shares in revenue.

Our contribution to the literature is threefold.

First, we propose a new empirical measure of Total Factor Productivity Growth (TFPG) which takes into account possible biases coming from imperfect competition on both labor and output markets, whereas the analyses of Crépon *et al.* (2002) and Dobbelaere and Mairesse (2009) focus on the decomposition of the Solow residual, to show that it can be decomposed into a mark-up of price over marginal cost component, a scale factor, a factor reflecting union bargaining power, and a rate of technical change.

Second, in contrast to most of the literature following Hall's approach, we estimate market power including the user cost of capital stock.

Third, we measure the sensitivity of TFPG to an alternative specification of competition based on relative profits.

To our knowledge, the impact of the interaction between product market and labor market imperfections on TFPG has not been investigated before.

As the potential biases from assuming perfect competition in product

markets have long been recognized, our paper implements the Dobbelaere and Mairesse (2009) approach to correct estimated TFPG for biases arising from labor market imperfections. Taking advantage of a rich firm-level dataset of 22 Dutch manufacturing industries over the period 1989-2005, we investigate possible changes in TFPG, allowing for both labor and output market imperfections. We find that only in few sectors firms set their prices above their marginal costs, while workers are bargaining over their salaries in the majority of industries. At the manufacturing level, our results, compared with the Dobbelaere and Mairesse (2009) analysis on French manufacturing enterprises, indicate less imperfect competition on the output market (the price-cost markup is found to be 1.06 versus 1.17 for French firms) and more imperfect competition in the labor market (workers' bargaining power is 0.61 versus 0.44 for French data). Moreover, we find that deviating from the assumption of perfect markets implies a possible heterogeneity in production technologies and variable returns to scale within the 22 industries. We also find that, for many of these industries, firms' pricing behavior tends to be directly associated with the characteristics of their production technology, including changes in efficiency which translate into productivity growth. Our finding is in line with well known models of endogenous growth (for example, Romer, 1990; Grossman and Helpman, 1991; Aghion and Howitt, 1992). As a matter of fact, a decrease of the level of product market competition has a positive effect on productivity growth, by augmenting the monopoly rents that reward new innovation. Furthermore, connected to the innovation process and labor market imperfections, as in Aghion and Howitt (1994), we find that labor market imperfection yields a lower productivity growth rate. Firms are subject to idiosyncratic shocks due to product innovations calling for labor force reallocations. As the rigidity of the labor market does not allow firms from adjusting their labor factor, labor market imperfection then causes a lower innovation rate.

Next, as a measure of the sensitivity of TFPG to different competition measures, we derive an alternative specification of competition based on relative profits, as the price-cost markup may not fully describe possible effects of inefficiencies in production (Boone *et al.* 2005, 2007). Therefore, we compare the traditional markup measure to the profit elasticity and other measures of competition, like the Herfindahl index. The resulting "adjusted markup" does not add to the previously specified model any relevant information neither on the market structure, nor on the TFPG.

The paper is organized as follows. In Section 2, we formulate a TFPG measure that allows for market power and time-varying economies of scale, and use the traditional markup as measure for competition, but corrected for imperfect competition in the labor market. Section 3 describes the data and

reports results on market imperfection parameters. In Section 4 we report and concisely discuss results for the TFPG measure discussed in Section 2. In Section 5 we compare the markup derived in Section 2 with a competition measure based on relative profits. In the final section we conclude with some policy implications.

2 TFPG based on the markup as a measure of competition

Following Dobbelaere and Mairesse (2009), we derive the estimating equation for a setting of three inputs (capital, labor, and intermediate goods) under imperfect competition in the goods and labor markets.

Gross output, Y_{it}, relates to three specific inputs as follows:

$$Y_{it} = A_{it}F_i(K_{it}, L_{it}, M_{it}) \qquad i = 1, 2, \ldots N \quad t = 1, \ldots, T, \tag{1}$$

where K_{it} denotes capital, L_{it} labor, and M_{it} intermediate goods, the latter consisting of materials and energy, for firm i at period t. A_{it} is defined as TFP[1] and $F_i(\cdot)$ is assumed to be homogeneous of degree θ_{it}, so that growth in output can be decomposed into growth in technology and inputs by logarithmic differentiation of production function in equation (1) (see also equation (15) in Appendix A)

$$\frac{dY_{it}}{Y_{it}} = \frac{dA_{it}}{A_{it}} + \frac{K_{it}}{F(\cdot)}\frac{\partial F_i(\cdot)}{\partial K_{it}}\frac{dK_{it}}{K_{it}} + \frac{L_{it}}{F_i(\cdot)}\frac{\partial F_i(\cdot)}{\partial L_{it}}\frac{dL_{it}}{L_{it}} + \frac{M_{it}}{F(\cdot)}\frac{\partial F_i(\cdot)}{\partial M_{it}}\frac{dM_{it}}{M_{it}}. \tag{2}$$

Following the McDonald and Solow (1981) efficient bargaining model, in which both wage and employment are bargained between firms and their workers, it can be shown that the wage of workers is determined at a level which is higher than the firm's marginal revenue of labor, i.e., $\partial \ln Y_{it}/\partial \ln L_{ikt} = W_{ikt}L_{ikt}/Y_{it}P_{it}(Y_t)(1 - \ell_{it})$ (W_{it} is the negotiated wage, $P_{it}(Y_t)$ is the market price as a function of aggregate output, and ℓ_{it} is the Lerner index, see equation (23) in Appendix A). Hence, workers in firms with market power on the output market can earn wages that are much higher than the competitive industry wage level.

Introducing the nominal input prices R_{it}, W_{it}, and Z_{it} as firm i's rental price of capital, wage rate, and unit price for intermediate goods, respectively, the efficient bargaining model can be summarized as follows.

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[1]MFP (*Multi-Factor Productivity*) is sometimes used interchangeably with TFP, even if there is a slight difference between what they may include. Indeed, taking into account all the factors influencing output levels can be unrealistic, therefore MFP may be a more appropriate term to use. However, the term TFP continues to be used more widely.

The workers in the firm bargain with the firm over both the levels of employment L_{it} and of the wage W_{it}. According to McDonald and Solow (1981) the workers' objective in their efficient bargaining model can be specified in two alternative ways, i.e., either as the workers' (or the union's) aggregate gain from employment, $L_{it}(W_{it} - \overline{W}_{it})$, or, taking account of the unemployment benefits, as $L_{it}W_{it} + \overline{W}_{it}(N_{it} - L_{it})$, where $\overline{W}_{it}$ is the reservation wage (i.e. the theoretical wage valid on an imperfectly competitive output market and a perfectly competitive labor market), W_{it} the negotiated wage, and N_{it} is the labor supply. McDonald and Solow (1981) judge the first specification as the most appropriate one for real life. As a matter of fact, the unemployment benefits may vary in magnitude, duration, and eligibility (Bean 1994a); therefore, similarly to Dobbelaere and Mairesse (2009), we advocate McDonald and Solow's (1981) suggestion.

The firm's objective is to maximize its short run profit, given by the difference between the total revenue and the total costs, i.e., as $P_{it}(Y_t)Y_{it} - W_{it}L_{it} - R_{it}K_{it} - Z_{it}M_{it}$.

The efficient bargaining model can be written as a (multiplicative) weighted average of the workers' aggregate gain from employment and the firm's short run profit:

$$\max_{W_{it}, L_{it}, K_{it}, M_{it}} \left[L_{it}(W_{it} - \overline{W}_{it}) \right]^{\phi_{it}} \left[P_{it}(Y_t)Y_{it} - W_{it}L_{it} - R_{it}K_{it} - Z_{it}M_{it} \right]^{1-\phi_{it}}$$

where $\phi_{it} \in [0, 1]$ is the degree of workers' bargaining power.

The best-known formal solution to this efficient bargaining model is Nash's one. Hence, maximizing with respect to employment and wage, yields the reservation wage:[2]

$$\overline{W}_{it} = \frac{P_{it}(Y_t)}{\mu_{it}} \frac{\partial Y_{it}}{\partial L_{it}},$$

Having the equilibrium reservation wage, we can express the elasticity of labor θ_{iLt} as (see the last equation of Appendix B):

$$\theta_{iLt} = \mu_{it}s_{iLt} - \phi_{it}\mu_{it} + \phi_{it}\theta_{it}, \tag{3}$$

where s_{ikt} denotes the share of the cost of input k in the total production value of firm i, s_{iLt} is the share of the cost of labor, and θ_{it} is the returns to scale parameter.

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[2]The complete derivation of the efficient bargaining model is provided in Appendix B.

Firm i's elasticities of output with respect to capital, θ_{iKt}, labor, θ_{iLt}, and intermediate goods, θ_{iMt}, at period t can then be expressed as:

$$A_{it}\frac{\partial F_i(\cdot)}{\partial K_{it}}\frac{K_{it}}{Y_{it}} = \theta_{iKt} = \mu_{it}s_{iKt}, \tag{4}$$

$$A_{it}\frac{\partial F_i(\cdot)}{\partial L_{it}}\frac{L_{it}}{Y_{it}} = \theta_{iLt} = \mu_{it}s_{iLt} - \phi_{it}\mu_{it} + \phi_{it}\theta_{it}, \text{ and} \tag{5}$$

$$A_{it}\frac{\partial F_i(\cdot)}{\partial M_{it}}\frac{M_{it}}{Y_{it}} = \theta_{iMt} = \mu_{it}s_{iMt}, \tag{6}$$

so that only when the technology is constant returns to scale and the output and labor markets are perfectly competitive, the factor elasticities will be equal to the observed input shares. Due to the imperfect competition on the labor market, establishing the relationship $\theta_{it} = \sum_{k=1}^{J_i}\theta_{ikt} = \mu_{it}\sum_{k=1}^{J_i}s_{ikt} = \mu_{it}s_{it}$, suggested by Hall (1990), is no longer valid. Indeed, adding the right hand sides of equations (4)-(6), the correct relationship between θ_{it} and $\mu_{it}s_{it}$ is now:

$$\theta_{it} = \frac{\mu_{it}}{(1 - \phi_{it})}(s_{it} - \phi_{it}), \tag{7}$$

also depending on the labor market bargaining elasticity, ϕ_{it} (note that if $\phi_{it} = 0$ equation (7) can be rewritten as $\theta_{it} = \mu_{it}s_{it}$).

After an appropriate logarithmic differentiation, we substitute the output elasticities (4)-(6) into equation (2) and taking account of the production function in equation (1) and the corrected scale elasticity in equation (7), we solve for the TFPG rates Δa_{it} from the resulting output growth equation:

$$\begin{aligned}
\Delta y_{it} &= \mu_{it}s_{iKt}\Delta k_{it} + (\mu_{it}s_{iLt} - \phi_{it}\mu_{it} + \phi_{it}\theta_{it})\Delta l_{it} + \mu_{it}s_{iMt}\Delta m_{it} + \Delta a_{it} \\
&= \mu_{it}(s_{iKt}\Delta k_{it} + s_{iLt}\Delta l_{it} + s_{iMt}\Delta m_{it}) + \mu_{it}\frac{\phi_{it}}{(1 - \phi_{it})}(s_{it} - 1)\Delta l_{it} + \Delta a_{it}
\end{aligned}$$

where lower-case letters denote variables expressed in logarithms.
This equation is derived, as in Dobbelaere and Mairesse (2009), without assuming a constant returns to scale technology or perfect competition neither in the output market, nor in the labor market. However, Dobbelaere and Mairesse (2009) end up with a different expression, because they avoid the computation of the user cost of capital, by estimating an (average) elasticity of scale θ or by assuming approximately constant returns to scale ($\theta = 1$) (Crépon *et al.*, 2002).

Defining $\Delta x_{it} \equiv s_{iKt}\Delta k_{it} + s_{iLt}\Delta l_{it} + s_{iMt}\Delta m_{it}$ and $\mu_{it}\phi_{it}/(1-\phi_{it}) \equiv \gamma_{it}$, we can rewrite our estimating equation in a compact form:[3]

$$\Delta y_{it} = \mu_{it}\Delta x_{it} + \gamma_{it}(s_{it}-1)\Delta l_{it} + \Delta a_{it} \tag{10}$$

where the bargaining elasticity satisfies $\phi_{it} = \gamma_{it}/(\gamma_{it}+\mu_{it})$.

We assume that the *Hicks-neutral* technological progress is a random variable such that firm i's growth rate in period t consists of a firm-specific growth rate, a_i, and a period-specific growth rate, δ_t, which captures the macroeconomic shock that is common across industries in the same period, plus a white noise, u_{it}. Therefore $TFPG \equiv \Delta a_{it} = a_i + \delta_t + u_{it}$. Moreover, productivity shocks u_{it}, such as positive technology shocks, might affect the level of factor inputs. It is indeed a plausible assumption that the composite error Δa_{it} includes an unobservable component which is taken into account in the firm's information set before input choices are made. The existence of such components raises the possibility that the input choices are correlated with u_{it}. Hence, we treat all firm-specific variables as potentially endogenous.

Under the profit-maximizing approach, provided that the firm's perceptions of the elasticities of demand remain unchanged, the markup would remain constant over time (μ_i). Once a firm has discovered a markup of price over marginal costs which serves its purposes, it is quite likely that it will maintain that markup (Coutts *et al.*, 1978).[4] The constancy over time

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[3]Without having reliable data on the share of capital, s_{iKt}, model (10) can be rewritten using Hall's (1990) original decomposition of the Solow residual. Defining the Solow residual for three inputs, denoted by q_{it}, as the difference between the output growth rate and the input share weighted average of the input growth rates:

$$q_{it} \equiv \Delta y_{it} - s_{iLt}\Delta l_{it} - s_{iMt}\Delta m_{it} - (1 - s_{iLt} - s_{iMt})\Delta k_{it}, \tag{8}$$

we can substitute the (first) output growth equation in (10) with the elasticity of capital $\theta_{iKt} = \mu_{it}s_{iKt}$ replaced by $\theta_{it} - \theta_{iLt} - \theta_{iMt} = \theta_{it} - (\mu_{it}s_{iLt} - \phi_{it}\mu_{it} + \phi_{it}\theta_{it}) - \mu_{it}s_{iMt}$ herein, so that for $\Delta x_{it} \equiv (\Delta l_{it} - \Delta k_{it})s_{iLt} + (\Delta m_{it} - \Delta k_{it})s_{iMt}$, the Solow residual (8) can be rewritten as:

$$q_{it} = \Delta a_{it} + (\mu_{it}-1)\Delta x_{it} + (\theta_{it}-1)\Delta k_{it} - \phi_{it}(\mu_{it}-\theta_{it})(\Delta l_{it}-\Delta k_{it}). \tag{9}$$

Hence, the often very volatile firm-level output growth should no longer be explained according to (10) but the much smoother Solow residual could be explained according to (9), again with TFPG decomposed as $\Delta a_{it} = a_i + \delta_t + u_{it}$.

[4]A supplementary estimation has been carried out for the time-varying markups μ_{it} and the bargaining power parameters ϕ_{it}, by introducing general third-order polynomials in time:

$\mu_{it} \equiv \beta_{i0}^{\mu} + \beta_{i1}^{\mu}t + \beta_{i2}^{\mu}t^2 + \beta_{i3}^{\mu}t^3$ and $\phi_{it} \equiv \beta_{i0}^{\phi} + \beta_{i1}^{\phi}t + \beta_{i2}^{\phi}t^2 + \beta_{i3}^{\phi}t^3$.

Parameter heterogeneity across industries is modeled as stochastic variation by performing Swamy's (1970) random-coefficients linear regression model. A comparison between

does not rule out the possibility for the structural parameters μ_{it} and ϕ_{it} to vary across firms.[5]

In this paper, we are going to apply model (10) on yearly firm level data for the Netherlands.

3 Data and results

We extract data from Statistics Netherlands for the years 1989-2005. The output and the input variables are defined as follows. As an output measure, we use the value of gross output ($P_{it}Y_{it}$) of each firm i. Labor (L_{it}) refers to the number of employees in each firm for each year,[6] collected in September of that year. The corresponding wages (W_{it}) include the total labor costs (gross wages plus salaries and social contributions) before taxes. The costs of intermediate inputs ($Z_{it}M_{it}$) include costs of energy, intermediate materials and services. The user costs of capital stock ($R_{it}K_{it}$) are calculated as the sum of the depreciation of fixed assets and the interest charges.

We use a two-digit NACE deflator of fixed tangible assets calculated by Statistics Netherlands in order to compute the volume index of capital stock (with net capital growth Δk_{it}). The nominal gross output and intermediate inputs are deflated with the appropriate price indices from the input-output tables available at the NACE rev. 1 two-digits sector classification.[7]

The data extracted from the Production Survey (PS) constitutes a highly unbalanced panel data (with a minimum of 1259 firms in 1994 and a maximum of 6277 enterprises in 1997) with 73427 observations spanning over 16 years and over 22 industries. For some firms, we observed negative correlation between the capital growth rate and the output growth. As a matter of fact, if the firm produces non-tangible goods, even if capital assets are growing, the physical output is decreasing as it acquires more technology,

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constant and time-varying markups shows that variation over time does not affect the size or the pattern of TFPG. Results are not reported here, but available upon request.

[5]Due to the generally scarce number of time observations per firm, we will estimate the parameters μ_{it} and ϕ_{it} as if they were constant over time and across firms. The effects of such aggregation may result in a misspecification of the firm-specific growth rate, a_i. Therefore, in Subsection 3.2 we will consider a more appropriate level of aggregation (industry-level).

[6]For each enterprise, jobs are added and adjusted for part-time and duration factors, resulting in number of man/years expressed as Full Time Equivalents (FTEs)(*Source: Statistics Netherlands*)

[7]NACE Rev. 1 is a 2-digit activity classification which was drawn up in 1990. It is a revision of the General Industrial Classification of Economic Activities within the European Communities, known by the acronym NACE and originally published by Eurostat in 1970.

which allows the enterprise to reduce the output volume. Since our specification of a production function is meant to represent manufacturing firms only, we exclude this type of firms.[8] Moreover, for the estimates, we only include firms for which we have at least two consecutive observations for all variables, ending up with 7161 firms. Throughout our sample period, the PS surveys included some changes in their population designs resulting in an unbalanced panel of the entire population. As a result, we cannot distinguish whether the entry or exit rates of firms resulted from survey response behavior or real economic structural behavior. The number of firms (N_j) for each NACE rev. 1 industry is calculated by Statistics Netherlands. Table ?? in Appendix C reports the sectors that were chosen with a corresponding NACE two-digit code and the corresponding number of firms.

3.1 Empirical results for the complete sample of Dutch firms

Table 1 reports the means, medians, standard deviations, and first and third quartiles of the included data for our main variables. A summary of the aggregate annual growth of all inputs and output along with input shares in revenue is presented. During 1989-2005, the gross output and the material input grew at a rate of about 1.7 and 1.9 percent annually, respectively. The annual capital growth rate is dramatically higher than the labor growth rate, implying increased capital intensity over time. However, the capital input constitutes only 4.9 percent of gross output on the average, while the mean share of labor is almost 28 percent, and intermediate inputs constitute more than half of gross output (60.65 percent on the average). Moreover, the dispersion of all these variables is considerably large.

As we defined TFPG consisting of a firm-specific growth rate, a_i, a period specific growth rate, δ_t, plus a white noise, u_{it} that might be correlated with the firm's input choices, estimating equation (10) by means of Ordinary Least Squares (OLS) estimates might be inconsistent and biased.

The estimation of a panel data model with predetermined variables is typically done by means of Generalized Method of Moments (GMM) estimators applied to the first differences transformation of the equation of interest, where the available lags of the predetermined variables are used as instruments. The purpose of this approach is to remove time-invariant unobserved individual heterogeneity. Therefore, under the assumption that the

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[8]In the original dataset, capital growth rates ranged from -359163 % to 802664 %. By choosing cut-off values of -7.69 % and 26.69 %, we kept data between the 10th and the 90th percentile, respectively.

Table 1: Descriptive Statistics

	mean	st.dv.	p25	median	p75
Δy_{it}	0.017	0.174	-0.060	0.015	0.098
Δm_{it}	0.019	0.229	-0.080	0.015	0.124
Δk_{it}	0.076	0.087	0.001	0.066	0.144
Δl_{it}	0.000	0.128	-0.046	0.000	0.047
s_{iMt}	0.606	0.148	0.511	0.609	0.705
s_{iKt}	0.049	0.042	0.023	0.040	0.064
s_{iLt}	0.278	0.131	0.185	0.267	0.356
Δx_{it}	0.019	0.153	-0.050	0.014	0.086
s_{it}	0.953	0.096	0.890	0.942	0.983
T/firm	4.3	1.8	2	4	6

Note: $\Delta x_{it} \equiv s_{iKt}\Delta k_{it} + s_{iLt}\Delta l_{it} + s_{iMt}\Delta m_{it}$; the number of time observations per firm varies between 2 and 16 years (30660 obs. for 7161 firms); p25 and p75 are the 25th and the 75th percentile, respectively.

current random shocks are serially uncorrelated[9] and defining $w_{it} \equiv (\Delta x_{it}, (s_{it}-1)\Delta l_{it})'$, the orthogonality conditions can be written as $E(w_{it-j}u_{is}) = 0$, for $j = 2, 3..., T$. The instruments we use are therefore lagged values of Δx_{it} and $(s_{it} - 1)\Delta l_{it}$ from $(t - 2)$ and before. In addition, we also include time dummies to capture possibly unobservable shocks common to all firms.

However, this approach yields inaccurate estimates in the case of a panel with a small number of time periods with highly persistent data. In this context, as has been stressed in Mairesse and Hall (1996), the application of first-difference GMM estimators with lagged levels of the series as instruments has produced unsatisfactory results. More specifically, the coefficient of the capital stock is generally low and statistically insignificant, and returns to scale appear to be unreasonably low. Blundell and Bond (1999) suggest that the problem of "weak instruments" is behind the poor performance of standard GMM estimators in this context. This problem of weak instruments can be overcome by applying an extended GMM estimator proposed by Arellano and Bover (1995). This estimator, labeled as "system GMM", is based on an augmented system which includes level equations with lagged differences as instruments in addition to the equations in differences with lagged levels as instruments.

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[9]When a variable is predetermined, the current period error term u_{it} is uncorrelated with current and lagged values of the predetermined variable but may be correlated with future values. An unpredictable technology shock will be uncorrelated with past (and potentially current) production settings, but will surely be correlated with future ones.

First, we focus on the manufacturing industry as a whole over the period 1989-2005, without looking at the potential heterogeneity in the mark-up and the bargaining power parameters among sectors. Estimation results for the entire manufacturing market are reported in Table 2 and are organized in two parts. The first three columns display the estimated structural parameters of our estimating equation (10) for a range of estimators (level OLS, first-difference OLS, first-difference GMM). The last two columns report the results of estimating a dynamic specification of equation (10), allowing for an autoregressive component in the productivity shocks.

The first section of each part of the table gives the estimated price-cost mark-up $\widehat{\mu}$, the corresponding rent sharing $\widehat{\phi}$ and the estimated scale elasticity $\widehat{\theta}$.[10] The second and the third sections present production function coefficient estimates assuming perfect competition in the output market ($\mu_{it} = 0$) and in the labor market ($\phi_{it} = 0$), respectively.

In the first two columns of Table 2 (OLS and first-difference OLS) we observe that the derived price-cost markups are not significantly different from 1 and the corresponding extent of rent sharing are quite small (respectively 0.268 and 0.278). Furthermore, both level OLS and first-difference (FD) OLS[11] suggest decreasing returns to scale. The main drawbacks to these estimators are that part of the information in the data is left unused. A fixed-effect estimator uses only the across time variation, which tends to be much lower than the cross-section one for not particularly persistent data. Second, the assumption that the firm's specific attributes are fixed over time may not always be reasonable. Although biased, OLS estimators of the Hall (1988) approach, which assumes an allocative wage ($\phi_{it} = 0$), generates a limited downward bias of price-cost markups (from 0.994 to 0.991 for the level OLS and from 0.988 to 0.985 for the FD OLS) and an upward bias of return to scale parameters (from 0.905 to 0.926 and from 0.884 to 0.921 for level OLS and FD OLS respectively). Intuitively, the underestimation of the markups, ignoring imperfect competition in the labor market, corresponds to the omission of the part of product rents captured by the workers, which are hidden in a larger scale parameter. On the other hand, when holding the markups fixed at 1, the rent sharing parameter slightly increases.

As stressed above, the OLS methods tend to underestimate the structural coefficients when the error term of the production function is expected

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[10]We use equation (7) to retrieve the parameter $\widehat{\theta}$. The standard errors of $\widehat{\phi}$ and $\widehat{\theta}$ are computed using the delta method (Greene, 1993).

[11]The two estimators give us more or less the same results as a consequence of estimating a static model. However, the FD estimator has the weaker exogeneity assumption that permits future values of production factors to be correlated with the error. This results in a light downwards bias of the markup and elasticity of scale.

Table 2: General results for all 22 industries

	STATIC			DYNAMIC	
	$LEVEL\ OLS$	$FD\ OLS$	$FD\ GMM$	$FD\ GMM$	$SYS\ GMM$
$\widehat{\phi}$	0.268	0.278	0.614	0.434	0.319
	(0.044)	(0.058)	(0.054)	(0.024)	(0.035)
$\widehat{\mu}$	0.994	0.988	1.063	1.010	1.026
	(0.006)	(0.008)	(0.026)	(0.013)	(0.012)
$\widehat{\theta}$	0.905	0.884	0.993	0.894	0.906
	(0.006)	(0.026)	(0.025)	(0.012)	(0.008)
$\widehat{\varphi}$				-0.018	-0.013
				(0.009)	(0.009)
Hp: $\mu = 1$					
$\widehat{\phi}$	0.269	0.278	0.621	0.4202	0.453
	(0.044)	(0.057)	(0.056)	(0.024)	0.057
$\widehat{\theta}$	0.910	0.909	0.910	0.887	0.880
	(0.002)	(0.001)	(0.040)	(0.002)	(0.004)
$\widehat{\varphi}$				-0.132	-0.141
				(0.014)	(0.019)
Hp: $\phi = 0$					
$\widehat{\mu}$	0.991	0.985	1.044	0.988	1.034
	(0.006)	(0.008)	(0.027)	(0.008)	(0.059)
$\widehat{\theta}$	0.926	0.921	0.976	0.924	0.952
	(0.006)	(0.008)	(0.025)	(0.007)	(0.012)
$\widehat{\varphi}$				-0.021	-0.005
				(0.008)	(0.008)
Test of overidentifying restrictions χ^2_{df}			1.719	348.624	64.661
			$df=4$	$df=26$	$df=40$
			$pval=0.423$	$pval=0.000$	$pval=0.008$
Time dummies			Yes		
N. firms			7161		

Note: Standard errors in parentheses; sample period 1989-2005; dependent variable: output growth Δy_{it}

to influence the choice of factor inputs and when the data do not exhibit a persistent structure (i.e., the across time variation is much lower than the cross-section one). Despite the signal of non persistency, we estimate a dynamic panel data model by considering an AR(1) extension of (10) and report the estimated coefficients in the second part of Table 2 (columns 4 and 5). We report results for the two-step GMM estimator for both the first differenced equations (FD GMM) and the system (SYS GMM). Year dummies have been included in both models.

At a first glance, it is clear that the AR(1) structure that we assume for the idiosyncratic error term is not needed, as the coefficient φ of the lagged dependent variable is statistically not significant for the system GMM, and although statistically significant for the FD GMM, it is approximately equal to zero in this case. Nevertheless, the gains of the system GMM estimation, claimed to be a more robust estimator (Arellano and Bover, 1995; Blundell and Bond, 1999), compared with the FD GMM estimates, are not very apparent in terms of an economically meaningful interpretation. All structural parameters behave similarly to the OLS estimators.[12] The markups equal to 1 and the corresponding bargaining power parameters are slightly larger (0.434 and 0.319, respectively, for FD and system GMM). Accounting for imperfect competition on the labor market yields to larger returns to scale than assuming perfect competition.

FD GMM estimates of equation (10) are displayed in the third column of Table 2. The parameter of bargaining power $\widehat{\phi}$ is very high (0.614), reflecting the influence of labor behavior on output growth. Nevertheless, taking into account the existence of rent sharing translates in a rise in the estimated markup $\widehat{\mu}$ (from 1.044 to 1.063) and in the estimated elasticity of scale $\widehat{\theta}$ (from 0.976 to 0.993). Our last estimation technique allows us to draw some conclusions for the Dutch manufacturing industries. In particular, we find some evidence of imperfect competition on the output market and strong union's power on the labor market. Markups are significantly and fairly larger than one and returns to scale are constant or moderately decreasing, in the range of 0.9 to 1.0.

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[12]To show the inapplicability of a dynamic panel data model to our data, we estimated the parameters of interest in the steady state equilibrium. Results displayed in Table ?? of Appendix C corroborate our propensity for a static model. Indeed, the steady state markup μ^* is smaller both in the FD GMM and the system GMM (0.976 and 1.012 respectively).

3.2 Across-Industry Estimates

Since firm's production behavior is very likely to vary even across industries, we also investigate across-industry firm heterogeneity in estimated markup and rent-sharing parameters.

For 22 industries, we estimate equation (10) with and without the extension to labor imperfections, by means of the FD GMM estimator as this allows us to provide a plausible economic interpretation and it is a robust estimation technique. As instruments we take an appropriate number of lagged levels. Year dummies are always included. The estimated parameters are reported in Table 3.

Results show that for all industries, the magnitude of the estimated markup, elasticity of scale and bargaining power are likely to vary among industries. The price cost margin μ is estimated to be lower than 1.01 for the first quartile of industries and higher than 1.16 for the top quartile. However, almost all industries reveal constant or increasing returns to scale (that is likely to be the case for manufacturing industries).

Within-industry imperfect competition on the labor market is present in 13 sectors. Then we reshape our results, by considering two subsamples. The first subsample (Table 4) includes the estimates showing evidence of perfect competition on the output market (price-cost markup less than or equal to 1). The second subsample (Table 5) contains the estimates of those sectors for which the price-cost markup exceeds 1.[13] Moreover, each table has two extra columns where we consider subsamples of sectors. The first extra column displays results for industries where the extent of rent sharing is found to be significant and bounded between 0 and 1 ($\mu \leq 1$ and $\phi \neq 0$). The second subsample includes the estimates for those sectors showing no evidence of rent sharing ($\mu \leq 1$ and $\phi = 0$).

Estimates of Table 4 are in line with what we found up to now. Taking into account the existence of rent sharing increases the estimated markup μ. This result is further confirmed by the subsample of 4263 firms for which the bargaining power was found to be significantly different from zero. The consequent decrease in the estimated elasticity of scale θ due to a reallocation of resources is more apparent in the second part of Table 4 (i.e., the two extra columns), where from a decreasing returns to scale (0.822) we move to an approximately constant elasticity of 0.95. Furthermore, we find strong evidence of large union's power (0.611 for all sectors where $\mu \leq 1$ and 0.65 for the first subsample).

However, the 5 sectors for which estimates are reported in Table 5 behave

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[13]According to Table 3, the selected sectors that exhibit $\mu > 1$ (significance at 5%) are 29, 30, 33, 34, 35.

Table 3: FD GMM estimates for 22 industries

NACE	$\widehat{\phi}$	$\widehat{\mu}$	$\widehat{\theta}$	$\overline{\Delta a}$	Hp:$\phi = 0$		N.obs(T/firm)
					$\widehat{\mu}$	$\widehat{\theta}$	
15	1.305	1.031	1.251	0.02	1.018	0.951	1168(3.8)
	(0.891)	(0.042)	(0.847)		(0.042)	(0.039)	
16	0.143	1.107	1.019	0.47	1.119	1.047	16(3.8)
	(0.089)	(0.168)	(0.156)		(0.205)	(0.192)	
17	0.288	1	0.887	1.51	1.042	0.974	286(3.6)
	(0.185)	(0.044)	(0.103)		(0.108)	(0.101)	
18	0.693	0.977	0.780	5.53	0.853	0.825	142(2.8)
	(0.092)	(0.035)	(0.067)		(0.064)	(0.152)	
19	0.307	0.958	0.961	7.02	1.014	0.948	83(3.4)
	(0.033)	(0.152)	(0.924)		(0.130)	(0.122)	
20	-0.495	0.982	0.933	0.49	0.984	0.920	262(3.7)
	(7.333)	(0.098)	(0.190)		(0.089)	(0.083)	
21	0.647	1.118	1.187	1.46	1.035	0.967	289(4.0)
	(0.135)	(0.162)	(0.204)		(0.091)	(0.085)	
22	0.825	1.330	1.346	-0.87	1.073	1.003	840(3.5)
	(0.045)	(0.213)	(0.211)		(0.213)	(0.199)	
23							15(2.6)
24	0.761	1.025	1.054	1.49	0.994	0.929	508(3.9)
	(0.068)	(0.094)	(0.100)		(0.092)	(0.086)	
25	0.708	1.182	1.223	0.72	1.023	0.956	540(3.3)
	(0.113)	(0.119)	(0.117)		(0.049)	(0.046)	
26	0.579	1.169	1.294	1.42	1.077	1.007	428(4.2)
	(0.083)	(0.112)	(0.196)		(0.088)	(0.082)	
27	1.207	0.946	0.936	2.46	0.975	0.912	146(4.6)
	(0.741)	(0.086)	(0.077)		(0.052)	(0.048)	
28	0.697	1.020	1.070	-0.30	1.013	0.947	1391(3.6)
	(0.073)	(0.040)	(0.059)		(0.040)	(0.038)	
29	0.789	1.238	1.339	-0.68	1.229	1.148	1047(3.1)
	(0.128)	(0.086)	(0.094)		(0.065)	(0.061)	
30	0.903	1.720	1.727	8.77	1.341	1.254	36(2.4)
	(0.019)	(0.166)	(0.165)		(0.152)	(0.142)	
31	-1.275	1.009	0.967	0.88	1.004	0.967	265(3.4)
	(3.457)	(0.071)	(0.072)		(0.072)	(0.072)	
32	1.468	1.047	1.031	5.94	1.196	1.118	69(2.4)
	(0.929)	(0.189)	(0.173)		(0.057)	(0.053)	
33	0 .906	1.130	1.137	-0.50	1.035	0.967	250(3.2)
	(0.034)	(0.065)	(0.065)		(0.080)	(0.075)	
34	0.798	1.324	1.344	3.02	1.341	1.282	210(3.6)
	(0.450)	(0.087)	(0.141)		(0.093)	(0.089)	
35	0.666	1.151	1.208	-2.98	1.102	1.031	217(3.2)
	(0.146)	(0.047)	(0.092)		(0.039)	(0.036)	
36	0.602	1.045	1.161	-0.10	1.046	0.978	454(3.4)
	(0.079)	(0.077)	(0.163)		(0.077)	(0.072)	

Note: Standard errors in parentheses; sample period 1989-2005; dependent variable: output growth Δy_{it}; $\overline{\Delta a}$ is the average TFPG.

Table 4: 17 Sectors where $\widehat{\mu} \leq 1$

	$\widehat{\mu} \leq 1$	$\widehat{\mu} \leq 1$ and $\widehat{\phi} \neq 0$	$\widehat{\mu} \leq 1$ and $\widehat{\phi} = 0$
$\widehat{\widehat{\phi}}$	0.611	0.650	
	(0.059)	(0.054)	
$\widehat{\widehat{\mu}}$	1.022	1.034	
	(0.027)	(0.035)	
$\widehat{\widehat{\theta}}$	0.847	0.822	
	(0.022)	(0.028)	
Hp: $\phi = 0$			
$\widehat{\widehat{\mu}}$	1.000		1.007
	(0.028)		(0.045)
$\widehat{\widehat{\theta}}$	0.933		0.950
	(0.026)		(0.043)
N.firms	6052	4263	2165

Note: Standard errors in parentheses; sample period 1989-2005; dependent variable: output growth Δy_{it}

differently. Including the rent sharing slightly reduces the level of imperfect competition from 1.254 to 1.231. This result is in contrast with some empirical findings (Krueger and Summers, 1987, 1988; Katz and Summers, 1989). A possible interpretation could be that workers will tend to gain higher wage rents in those sectors where there is less competition, which in turn generates a surplus, to which workers have a claim of a share. In other words, workers' unions power, and in general rigidities of the labor market, will affect firms' marginal cost, and, consequently, the markups.

Therefore, rigidities and frictions in the labor market might be crucial for understanding firms' behavior. To the extent that wages are allocative, we find that labor market frictions are the key factor. However, the exact form of these frictions remains still ambiguous and will be a stimulus to carry on further research.

4 Impact on TFPG

Introducing imperfect competition on both output and labor markets, we see that changes in the level of competition vary by industry. This section incorporates these findings to analyze the relationship between imperfect competition, variable returns to scale, and productivity growth.

Table 5: 5 Sectors where $\widehat{\mu} > 1$

	$\widehat{\mu} > 1$	$\widehat{\mu} > 1$ and $\widehat{\phi} \neq 0$	$\widehat{\mu} > 1$ and $\widehat{\phi} = 0$
$\widehat{\widehat{\phi}}$	0.566	0.574	
	(0.323)	(0.321)	
$\widehat{\widehat{\mu}}$	1.231	1.210	
	(0.082)	(0.093)	
$\widehat{\widehat{\theta}}$	1.063	1.035	
	(0.071)	(0.081)	
Hp: $\phi = 0$			
$\widehat{\widehat{\mu}}$	1.254		1.341
	(0.066)		(0.093)
$\widehat{\widehat{\theta}}$	1.179		1.282
	(0.062)		(0.089)
N.firms	1681	1498	210

Note: Standard errors in parentheses; sample period 1989-2005; dependent variable: output growth Δy_{it}

The effect of markups on TFPG, measured in a growth accounting framework, has been addressed in a number of related papers.[14] Azzam *et al.* (2004) decompose sources of TFPG by economies of scale, markups, and demand growth. Using US food industry data for 1973-1992, these authors find that, on average, productivity grew by 0.22% due to markups and 0.10% due to increases in economies of scale. Morrison (1992) finds that the TFPG adjusted for markups in total manufacturing has increased during 1960-1981 for Japan, the US, and Canada. It is also noted that variable returns to scale tend to neutralize the implications of the markup adaptation. Harrison (1994) measures changing markups and productivity of manufacturing firms in the Côte d'Ivoire. Annual TFPG measured as a Törnquist index number formula, (i) rises from 0.4% to 1.4% under the assumption of perfect competition and constant returns to scale, (ii) rises from 0.5% to 1.4% if the assumption of perfect competition is relaxed, and (iii) if both assumptions are relaxed, productivity growth rises from 0.6% to 1.8%. Kee (2004) finds that the average annual growth rate of the productivity of Singapore's

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[14]We note that there is also another strand of literature that (usually through regressions) looks immediately at the effect of competition and broader definitions of economic performance (including productivity). For a comprehensive survey of empirical studies, see Nickell (1996). The author concludes that the empirical evidence for the relation is not convincing.

Table 6: Averages of TFPG (%)

Hp:	All sectors		Sectors where $\widehat{\mu} > 1$		Sectors where $\widehat{\mu} \leq 1$	
	Mean	Median	Mean	Median	Mean	Median
I	0.95	0.93	2.30	1.50	0.94	0.91
II	1.00	1.00	2.60	2.40	1.03	1.04
III	-0.20	-0.10	0.02	0.23	-0.26	-0.16
IV	-0.73	-0.61	-0.47	-0.27	-0.78	-0.26

Note: I: $\phi \in (0, 1]$; II: $\phi = 0$; III: $\phi = 0, \mu = 1$; IV: $\phi = 0, \theta = \mu = 1$; TFP percentage growth rates are calculated as residuals (FD GMM).

manufacturing sector from 1974 to 1992 is 7% while the TFP index takes imperfect competition and non-constant returns to scale into account, whereas the TFPG is less than 3% by conventional measurement.

In a recent study, Van der Wiel and Van Leeuwen (2003) find evidence of an opposite effect in the (market) service sector when the TFPG is adjusted by a markup ignoring economies of scale. Based on firm-level data between 1994-1999; their study finds that the modified TFPG is 0.2% higher than the traditional TFPG.

In Table 6, we summarize our estimation results. In particular, when adopting the conventional framework of perfect competition and constant return to scale, the residually estimated productivity growth is -0.73 percent. When relaxing the assumption of constant returns to scale, the average (across years) TFP growth rate for all industries rises to -0.20. Moreover, introducing imperfect competition on the output market dramatically increases the productivity growth (1%). This finding is in line with the majority of models of endogenous growth (e.g Romer, 1990; Grossman and Helpman, 1991; Aghion and Howitt, 1992). Indeed, a decrease of the level of product market competition has a positive effect on productivity growth, by augmenting the monopoly rents that reward innovations.

Furthermore, connected to the innovation process and labor market imperfections, as in Aghion and Howitt (1994), we find that labor market imperfection results in a lower productivity growth rate (TFPG slightly decreases to 0.95 percent). As a matter of fact, firms are subject to idiosyncratic shocks due to innovations that are implicitly asking for labor force reallocations. Labor reallocation influences the productivity growth rate, as it determines the speed with which resources are moved around to the most profitable firms. As rigidity of the labor market does not allow firms from adjusting their labor factor, labor market imperfection then causes a lower innovation rate.

As in the previous section, we reshape our results, by considering two sub-

samples. One sample contains the estimates of those sectors for which the price-cost markup exceeds 1 and the other subsample considers the sectors showing evidence of perfect competition on the output market (price-cost markup less than or equal to 1). As expected, the average TFPG is remarkably higher for the first subsample of sectors (2.3%) than for the second one, where the mean TFPG is approximately the same as for the whole sample (0.94%). We also find that this downward effect on TFPG is particularly remarkable for those firms exhibiting higher markups. As a further analysis, we take into account the possibility of correlation between class size (number of employees) and productivity growth. Figure ?? in Appendix C shows no evidence of a distinct relationship between class size and TFPG. LOWESS[15] estimates of TFP growth rates for all sectors are graphed (Figure ?? in Appendix C), aiming at discerning a distinct pattern over time. Some industries clearly show a positive trend in the productivity growth; therefore, a non parametric test[16] to detect a significant trend over time is carried out. According to the results of Table ?? in Appendix C, only 4 out of 22 sectors have a significant trend at 5%. Food, beverages and tobacco, leather products, and motor vehicles exhibit a positive trend, while paper products, publishing and printing shows a decrease in TFPG .

5 TFPG based on an Alternative Measure of Competition

It is important to have indicators that measure market power in an unambiguous way. In the theoretical framework used to derive the markup measure of competition we did not account for possible dynamic effects caused by differences in efficiency. Indeed, there may also be problems that are inherent to the markup measure of competition. Using price-cost margins alone to assess market power can be misleading, because its theoretical robustness has been challenged by some authors (see Boone, 1997, 2000, 2001, 2004, and 2008; Amir, 2002; Hölzl, 2006; Koeniger and Licandro, 2006; and Boone *et al.*, 2005 and 2007). Therefore, it is possible that the markup distorts the picture of competition. Problems are twofold.

First, measures based on price-cost margins such as the markup have a tendency of cyclical behavior, especially in markets where goods are symmet-

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[15]The LOWESS smooth technique carries out locally-weighted time series smoothing for both equispaced and non-equispaced data; LOWESS stands for "locally weighted scatterplot smoothing" (Cleveland, 1979).

[16]Cuzick's trend test (1985) is an extension to a Wilcoxon-type test for trend across a group of three or more independent random samples.

rically differentiated and differ in their marginal costs. As an illustration, if firms' costs fall, the price-cost margin goes up, falsely suggesting a change in competition (Boone *et al.*, 2007). Moreover, as is established by Boone et al. (2007), a higher variance of the underlying cost distribution across firms causes the price-cost margin to be less successful as a measure of competition. Therefore, the cyclical behavior of the markup may not represent actual changes in competition.

A second problem with the markup measure is that it does not account for possible effects of inefficiencies in production. In particular, in case firms are heterogeneous over time with respect to efficiency of production, the markup may be a poor indicator of competition. To see this, note that there are two ways in which competition can be increased: (1) more entry of firms and (2) more aggressive behavior by firms leading to a reallocation of production towards the efficient firms.[17] The latter route may imply a change in market share composition or a reduction in the total amount of firms in case inefficient firms are driven out of the market, indicating that a concentration measure such as the Herfindahl-Hirschman index (HHI)[18] may point in the wrong direction. However, also a measure based on the price cost margin, such as the markup, may prove to be a wrong guide. In particular, because the allocation effect causes an increase of the market share of the efficient firms, price-cost margins may increase (Boone *et al.*, 2007). As illustrated by Boone *et al.* (2005), the unweighted price-cost margin can give a wrong impression of competition since it would falsely suggest a reduction in competition in case a new entrant has a relatively high Lerner index and hence low market share.

In a series of papers, Boone (1997, 2000, 2001, 2004, and 2008) and Boone *et al.* (2005 and 2007)) suggest an alternative competition measure, based on relative profits, which is theoretically more robust to a different parametrization of competition (e.g., number of firms, entry costs, interaction between firms, and cost reductions). This measure uses the effect of possible inefficiencies in a firm's production. In particular, the central idea of this alternative measure is that (i) competition always raises the profits of a more efficient firm relative to the profits of less efficient firms and (ii) a rise in competi-

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[17]For evidence on the importance of the second effect, consult Boone *et al.*, 2007.

[18]The Herfindahl-Hirschman index for each sector j is computed as: $HHI_{jt} = \sum_{i \in j}^{N} \left(\frac{Y_{it}}{\sum_{i \in j}^{N} Y_{it}} \right)^2$ .The HHI index will change if there is a shift in market share among the larger firms.

Exports of firm i are included in balance sheets of the firm. Hence the industry level Y_{jt} are generally higher than the national industry outputs.

tion reduces the profits of the least efficient firms active in the market. The reason is that the output of inefficient firms is reallocated to more efficient firms. More precisely, the relative profit measure captures the fact that, as competition increases, firms are punished more severely in terms of profits for a drop in efficiency. In this sense, cost differentials are translated into profit differentials. In this way the selection effect of competition arises: "a rise in competition separates efficient firms from inefficient firms by reducing inefficient firms' profits and thus forcing them to exit" (Boone (2000)).

Boone *et al.* (2007) find that measures based on relative profits and price-cost margins are highly correlated and that both tend to give an accurate view of competition. However, in situations where the reallocation effect is strong, i.e., in cases with few firms and high Herfindahl indexes, the measures deviate suggesting that in these instances measures based on price-cost margins fall short. Since this is likely to be relevant in the present study, we explicitly take the relative profit measure into account.

Boone's measure takes into account the fact that over time there may exist more efficient firms (with lower marginal costs) that have lower prices and higher profits, price-cost margins, and market shares. In the Boone *et al.* (2007) formulation for firm $i = 1, 2, \ldots, N$ belonging to sector j at period $t = 1, 2, \ldots, T$, logarithmic nominal profits can be written as a function of logarithmic unit nominal costs:

$$\ln \pi_{ijt} = \alpha_{ij} + \delta_{jt} - \beta_{jt} \ln c_{ijt} + \varepsilon_{ijt}, \tag{11}$$

where the fixed effects are given by α_{ij} and $\delta_{jt} = \ln \overline{\pi}_{jt} + \beta_{jt} \ln \overline{c}_{jt}$ with $\overline{\pi}_{jt}$ and $\overline{c}_{jt}$ are the reference profits and costs, respectively,[19] and ε_{ijt} are the error terms related to the unobservable parts of individual profits of the firm in sector j.

Since less efficient firms will have higher values of c_{it}, it generally holds that the firm in sector j with higher costs has lower profits, or (in general) $\beta_{jt} > 0$. The estimated β_{jt} elasticities measure to what extent cost efficiency differentials are translated into profit differentials, or in other words, "in a more competitive industry, firms are punished more harshly for being inefficient" (Boone, 2008, p. 1246). Hence, the values of β_{jt} inform about the

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[19]Substituting this expression for the fixed effects in (11), we directly observe that the basic profit function is expressed in relative terms:

$\ln \frac{\pi_{it}}{\pi t} = \alpha_i - \beta_t \ln \frac{c_{it}}{\overline{c}_t} + \varepsilon_{it}$.

The relationship between relative profits and relative cost efficiencies should be either expressed in terms of the most or the least efficient firm.

degree of monopoly or competition: as competition increases, the β_{jt}s become larger (in absolute value).

Under the assumption that measurement problems (e.g. data aggregation, unobservable marginal costs) stay constant over time within an industry, the relative profit indicator should merely be used as a tool that analyzes changes of competition over time within an industry.

Since Boone's profit elasticity is only given for sectors, we compare competition indicators at the industry level, j. Boone *et al.* (2007) also report the correlation of markups and relative profits. Based on a sample of 43 UK *industries* for 1986-1999, they find a significant positive correlation for 20 industries. As already pointed out, Boone *et al.* (2007) find that markups and the relative profit elasticities are highly correlated if the HHI is low. However, the analysis comparing profit elasticities with markups and their corresponding HHI may be misleading, because it is claimed that each of these three competition measures have a simultaneous relationship and other market determinants may also be important. Therefore, we establish the relationship between both measures controlling two important market characteristics. By deriving this relation we can obtain an adjusted markup level that enters the TFPG equation. In that sense, it allows us to measure the sensitivity of TFPG to both competition indexes.

To establish this relationship, we run the regression,

$$\widehat{\mu}_j = \widehat{\beta}'_j \omega_{j1} + H'_j \omega_{j2} + N'_j \omega_{j3} + \left(\widehat{\beta}_j \odot H_j\right)' \omega_{j4} + \left(\widehat{\beta}_j \odot N_j\right)' \omega_{j5} + \delta_t + \varepsilon_j, \quad (12)$$

where $\widehat{\mu}_j$ are the estimated markups, $\widehat{\beta}'_j = (\widehat{\beta}_{j1}, \widehat{\beta}_{j2}, ..., \widehat{\beta}_{jT})$ are the relative profit' elasticities that are derived from equation (11), $H'_j = (H_{j1}, H_{j2}, ..., H_{jT})$ are the HHIs per industry j, and $N'_j = (N_{j1}, N_{j2}, ..., N_{jT})$ are changes in the number of firms. Equation (12) simply relates the markups to other structural market variables, so that it may be reasonable to assume that the impact of these market variables accounts for cyclical changes and other possible determinants. It is not straightforward how these variables will relate to the markup measure. In *standard* theory, competition intensifies as the number of firms increases. This is based on the concept that an increase in the number of firms is regarded as an increase in competition, which may be due to lower barriers of entry. As a result of higher entry in the market, it can easily be verified that the markup will decrease when the number of firms increases. In general, the number of firms and the Herfindahl index are inversely related: the markup will decrease if the Herfindahl index decreases. Boone *et al.* (2007) have also pointed out that these effects may be ambiguous. An increase in competition by intensifying the number of firms may raise the market shares of the efficient firms at the cost of the inefficient ones

through the reallocation effect. By this mechanism, the Herfindahl index may increase contradicting standard theory. In addition, it is also claimed that markups and relative profit elasticities are highly correlated at low concentration. We therefore also control for some interaction effects where the Herfindahl indexes and the number of firms act like moderators.

The results for Dutch firms are discussed in the next section.

6 Data and Estimation Results

We note that the unbalanced nature of our panel data is caused by the different numbers of firms for each sector j and time t. The changing number of firms may be induced by either market exit or entry rates or some firms may not have been included in the PS statistics for a particular year. We note that large firms have always been included in the population surveys of the Dutch PS. However, lack of data did not allow us to distinguish one of these underlying reasons for the changing number of firms. Consequently, we matched the HHI to two alternative measures. First, we follow Nickell (1996) by defining the total sales as the average sales of firm i in industry j at time t multiplied by the number of firms in industry j chosen in a base year. The number of firms is kept constant over the years to correct for the changing firm base of the sample. The method of keeping the number of firms across time constant (for example by a base period, see Nickell, 1997) did not affect the results. As a second robustness check, we also find that our HHIs are very highly correlated (for matching sectors) with those computed from the Dutch National Accounts, based on an adjustment using a population raising factor to their sample.

Data on measuring profits and costs come directly from the Dutch PS. Profits are available as a separate variable reported by each of the firms collected in the survey. In the relative profits' competition indicator, costs are defined in terms of marginal costs (see Boone, 2000 - conjecture 1). However, it is difficult to measure marginal costs directly. To overcome this problem, Boone *et al.* (2007) measure a firm's cost efficiency by dividing total variable costs $(W_{it}L_{it} + Z_{it}M_{it})$ by revenue, $C_{it}Y_{it}/P_{it}(Y_t)Y_{it}$, where C_{it} is the firm's nominal marginal cost (for one unit of real output). Since the Y_{it} terms cancel out, this measure is equivalent to $C_{it}/P_{it}(Y_t)$, which is merely the unit marginal cost normalized by the output price $P_{it}(Y_t)$. Data for 22 dutch manufacturing sectors are again ranging from 1989 to 2005. Summary statistics on the variables involved in estimating equation (12) and equation.(11) are reported in Table 7. Boone *et al.* (2007) find that on average over 250 Dutch markets over the period 1993-2002 $\overline{\beta}_{jt}$ equals 7. Our

Table 7: Summary statistics

	Obs	Mean	Std. Dev.	Min	Max
$\widehat{\mu}_{jt}$	321	1.118	0.186	0.87	1.72
H_{jt}	336	0.130	0.204	0.004	0.913
N_{jt}	336	0.805	0.135	0.376	1
$\widehat{\beta}_{jt}$	337	9.274	2.788	4.502	16.600
c_{it}	30660	0.884	0.103	0.066	1.884
$\pi_{it} \geq 0$	27339	7.155	1.697	0	14.774

Note: $\widehat{\mu}_{jt}$ is the estimated markup for sector j at time t; H_{jt} is the HHI per industry j at time t; $N_{jt} \in [0,1]$ measures the changes in the number of firms in sector j; $\widehat{\beta}_{jt}$ is the estimated profit elasticity per sector; c_{it} are the costs for firm i at time t; π_{it} is the log of profits > 0.

data report evidence of a more intense imperfect competition: $\widehat{\beta}_{jt}$ is equal to 9.3, that is a one percent increase in costs leads to a 9.3 percent reduction in profits. However, there is substantial variation in $\widehat{\beta}_{jt}$, and the patterns of the estimated slope parameter change over time (see Figure **??** in Appendix C). The high profitability present in the manufacturing market attracts new firms, and results in a growth of number of firms N_{jt} (80.5%). However, the measure of concentration H_{jt} points at a moderate (ranging between 0.10 and 0.18) level of competition. Our empirical model (12) is estimated with linear instrumental variables regression (IV) on Dutch manufacturing firms that report non-negative profits.[20]

We are interested in the impact that an encompassing measure of competition would have on the productivity growth. Therefore, we plug the systematic part of equation (12) in equation (10) to see whether an empirically more robust measure of competition will affect the magnitude of the other structural parameters. Table 8 shows quite sizable differences. The average of the empirical markup over time is higher (1.09) than the FD GMM estimate of μ_{it} (1.06). Nevertheless, with the new adapted markup we find moderately decreasing returns to scale, 0.90, while with the classical specification of the competition measure we could not reject the hypothesis of constant returns to scale. However, the TFPG seems not to be affected by the different specification, as it is found to be 0.97 percent. A paired t-test reveals that the mean differences between productivity calculated with the classical specification of markup (0.95) and productivity estimated taking into account the inclusion of the adapted markup (0.97) is not significantly

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[20]Firms with zero profits are included in the sample, since we considered the logarithm of one in such case.

Table 8: Estimates of eq. (10) using the "adjusted markup" of eq. (8)

	$\widehat{\phi}$	$\widehat{\mu}$	$\widehat{\theta}$	N.
eq.(8)	0.614 (0.054)	1.063 (0.026)	0.993 (0.025)	7161
eq.(10) with $\widehat{\mu}_{jt}$ of eq. (12)	0.631 (0.050)	1.090 (0.010)	0.898 (0.034)	7161

Note: Std. err. in parentheses; sample period 1989-2005; dependent variable: output growth Δy_{it}.

different from zero. Hence, adding more structure to the competition measure does not tell us anything more on productivity change. A possible conclusion could be that the specification of a the output growth according to equation (10) already covers the mechanism of competition between firms and workers. Taking into account both competition on the output market and on the labor market is a more complete description of what is considered by the profit-maximizing firm. Indeed, including frictions and rigidities of the labor market in the production function, already corrects for that part of profits that would result in a higher gain for the firm. If profits are balanced between firms and workers, the resulting markups will be then already corrected for efficiency gains. Therefore, the profit elasticity does not add information on efficiency as this is implicitly, but already included in our model (10).

As a matter of fact, estimates of the empirical model reported in equation(13) below, validate our finding of scarce contribution of the profit elasticity in adding elements to market behavior analysis. The estimated empirical relationship (standard errors in parentheses, time dummy included) is therefore reported:

$$\widehat{\widehat{\mu}}_j = \underset{(0.032)}{-.068}\,\widehat{\beta}_j - \underset{(0.122)}{0.507}H_j \underset{(0.430)}{-0.949}\,N_j + \underset{(0.010)}{0.049}\,\widehat{\beta}_j * H_j + \underset{(0.039)}{0.076}\,\widehat{\beta}_j * N_j \quad (13)$$

In line with the IO literature, an increase on the number of firms (N_j) has a downward effect on the markup. The negative coefficient of the Herfindhal index is consistent to what is expected. An increase in concentration leads to a reduction of price-cost margins. Average marginal effects are then computed. The marginal effect of the profit elasticity $\widehat{\beta}_j$ is found to be -0.0003 and statistically significant only at 25%; the average marginal effect of H_j is -0.025, and that of N_j is -0.21 (both significant at 5 percent). However, these results are generally consistent with both theory and Boone et al. findings, in the sense that coefficients have the expected negative signs.

7 Conclusion

In this paper, we explore both theoretically and empirically a framework where we integrate possible labor market rigidities and output market behavior on total factor productivity growth (TFPG) measure. We consider market power measured by the traditional markup, and we propose an alternative markup proxy, that should capture possible effects of inefficiencies in production. This adapted markup relates the classical markup to relative profit elasticities, the Herfindahl index, and other market structural variables.

Embedding Hall's (1990) efficient bargaining model, which introduces a substantial degree of labor market imperfections, we show that rigidities and frictions in the labor market might be crucial for understanding the firms' marginal costs and their price setting behavior. We apply this analysis to 22 industries in Dutch manufacturing for the period 1989-2005.

By comparing a range of estimators (level OLS, first-difference OLS, first difference GMM, Arellano and Bond, Blundell and Bond), we estimate a standard production function, allowing for an autoregressive component in the productivity shocks.

We show some evidence of imperfect competition on the output market and strong union's power on the labor market. Markups are significantly and fairly larger than one and returns to scale are constant or moderately decreasing, in the range of 0.9 to 1.0. On the other hand, our data do not support the AR(1) structure that we assume for the idiosyncratic error term.

The variation of imperfect competition across sectors is then large. The price-cost margin is lower than 1.01 for the first quartile of industries and higher than 1.16 for the top quartile. Workers' union power also takes values that range from 0.143 to 0.903, while returns to scale are likely to be homogeneously constancy across sectors.

To the extent that wages are allocative, we find that labor market imperfections play a main role in either determining the market behavior and in assessing the correct TFPG.

When adopting the conventional framework of perfect competition and constant return to scale, the estimated productivity growth is -0.7 %, while when relaxing it, the average TFPG for all industries rises to -0.02 %. Then, introducing imperfect competition on the output market dramatically increases the productivity growth (1%). Hence, a decrease of the level of product market competition has a positive effect on productivity growth. Furthermore, we find that labor market imperfection leads to a lower productivity growth rate (TFPG decreases to 0.95%).

On the other hand, the TFPG does not seem to be sensitive to our alternative specification of the markup, as TFPG is found to be of the same

magnitude of the one calculated with the classical specification of markups. We conclude that adding more structure to the competition measure does not add any information to productivity change and efficiency in general, as this is indirectly included in the previous specification.

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A Varying markups and returns to scale in a general setting

This Appendix presents a detailed analysis of the production function and the TFPG set-up allowing for market imperfections and scale economies. The derivation of markups, scale elasticities, and TFPG is based on a single-output production technology.

In particular, we let each firm $i \in \{1, \ldots N)$ face the following production function for period t:

$$Y_{it} = A_{it} F_i(\mathbf{X_{it}}) \qquad i = 1, 2, \ldots N \quad t = 1, \ldots, T, \tag{14}$$

where Y_{it} measures firm i's gross output, $\mathbf{X_{it}} \equiv (X_{i1t}, X_{i2t}, \ldots, X_{iJ_it})'$ denotes the vector of J_i nonnegative factor inputs, $F_i(.)$ is the core of the (differentiable) production function, and A_{it} is TFP measured as the rate of a Hicks-neutral disembodied technology. Logarithmic differentiation of production function (14) yields:

$$\frac{dY_{it}}{Y_{it}} = \frac{dA_{it}}{A_{it}} + \sum_{j=1}^{J_i} \frac{X_{ijt}}{F_i(\cdot)} \frac{\partial F_i(\cdot)}{\partial X_{ijt}} \frac{dX_{ijt}}{X_{ijt}}, \tag{15}$$

with $\frac{dY_{it}}{Y_{it}}$ (logarithmic) output growth and $\frac{\partial \log Y_{it}}{\partial t} = \frac{dA_{it}}{A_{it}}$ (logarithmic) TFPG.

How does imperfect competition enter (15)? Firms with market power do not set their value of the marginal product, $P_{it} A_{it} \frac{\partial F_i(\cdot)}{\partial X_{ijt}}$, equal to their corresponding factor price. It is assumed that each firm i faces an inverse demand function, $P_{it}(Y_t)$, which represents the market price as a function of aggregate (industry) output $Y_t \equiv \sum_{i=1}^{N} Y_{it}$, i.e., by specifying firm i's (output) price as an arbitrary function of aggregate output we allow for various potential degrees of firm i's market power on its output market.

Firm i's optimization problem can be written as:

$$\max_{Y_{it}, \mathbf{X}_{it}} \left\{ P_{it}(Y_t) Y_{it} - \mathbf{V}'_{it} \mathbf{X}_{it} \mid Y_{it} = A_{it} F_i(\mathbf{X}_{it}) \right\}, \tag{16}$$

where $\mathbf{V}_{it} \equiv (V_{i1t}, V_{i2t}, \ldots, V_{iJ_it})'$ is firm i's vector of J_i input prices. Assuming, in the first instance, that there is imperfect competition on the output market and perfect competition on the input markets (a monopolistic firm acting as a price-setter on its output market and a price-taker on its input markets), the first order conditions (FOCs) implied by the solution of (16) yield the following equations for the Lagrange multiplier and the nominal

input prices:

$$P_{it}(Y_t) + \frac{\partial P_{it}(Y_t)}{\partial Y_t}\frac{\partial Y_t}{\partial Y_{it}}Y_{it} = P_{it}^* \text{ and}$$

$$\left[P_{it}(Y_t) + Y_{it}\frac{\partial P_{it}(Y_t)}{\partial Y_t}\frac{\partial Y_t}{\partial Y_{it}}\right]\frac{\partial Y_{it}}{\partial \mathbf{X}_{it}} = \mathbf{V}_{it}, \tag{17}$$

where, according to Diewert (1993) and Diewert and Fox (2004), the Lagrange multiplier P_{it}^* is firm i's shadow or marginal price of output under profit maximization and market power enables firm i to set each input's marginal product, $\frac{\partial Y_{it}}{\partial X_{ikt}}$, above the respective factor cost, or:

$$\frac{\partial Y_{it}}{\partial X_{ikt}} = \left[\frac{1}{1 + \frac{\partial P_{it}(Y_t)}{\partial Y_t}\frac{Y_{it}}{P_{it}(Y_t)}}\right]\frac{V_{ikt}}{P_{it}(Y_t)} \text{ for } k = 1, \ldots, J_i, \tag{18}$$

where the term between square brackets is firm i's *markup*. Note that in case of perfect competition $\frac{\partial P_{it}(Y_t)}{\partial Y_t}$ goes to zero, implying that prices are set at marginal cost since marginal revenue (MR_{it}) is (always) equal to marginal cost (MC_{it}) (or $MR_{it} = P_{it}^* = MC_{it}$) and inputs are paid their marginal products (markup equal to 1) then.

For firm i, the first order condition with respect to output in (17) can be rewritten as:

$$\frac{P_{it}(Y_t) - MC_{it}}{P_{it}(Y_t)} = -\frac{\partial P_{it}(Y_t)}{\partial Y_t}\frac{Y_{it}}{Y_t}\frac{Y_t}{P_{it}(Y_t)} \tag{19}$$

or the Lerner index as a measure of a monopolist's market power is inversely related to the price elasticity of market demand:[21]

$$\ell_{it} = \frac{ms_{it}}{\varepsilon_{it}} \tag{20}$$

where $\ell_{it} \equiv \frac{P_{it}(Y_t) - MC_{it}}{P_{it}(Y_t)}$ is firm i's Lerner index or (relative) price-cost margin, $\varepsilon_{it} \equiv -\frac{\partial Y_t}{\partial P_{it}(Y_t)}\frac{P_{it}(Y_t)}{Y_t}$ is firm i's elasticity of demand with respect to price, and $ms_{it} \equiv \frac{Y_{it}}{Y_t}$ is its market share. The Lerner index (20) is defined in the range of $0 \leq \ell_{it} < 1$. Note that the markup (ratio) μ_{it}, which we define as the ratio of output price over marginal (production) cost, can easily be related to the Lerner index:

$$\mu_{it} \equiv P_{it}/MC_{it} = 1/(1 - \ell_{it}) \geqslant 1, \tag{21}$$

---

[21]The larger the elasticity of demand in absolute terms, the smaller the monopolistic firm's market power.

so that it becomes clear that, if firm i is not perfectly competitive, then the value of its marginal product exceeds its factor cost by some markup μ_{it} in (18), i.e.:

$$\mu_{it} = \left[\frac{1}{1 + \frac{\partial P_{it}(Y_t)}{\partial Y_t} \frac{Y_{it}}{P_{it}(Y_t)}} \right]. \tag{22}$$

From (19) we obtain that the second FOC in (17) can be rewritten as:

$$\mathbf{V}_{it} = P_{it}(Y_t)(1 - \ell_{it}) \frac{\partial Y_{it}}{\partial \mathbf{X}_{it}}$$

or for any individual input factor $k \, \epsilon \, J_i$:

$$
\begin{aligned}
P_{it}(Y_t)(1 - \ell_{it}) \frac{\partial \ln Y_{it}}{\partial \ln X_{ikt}} \frac{Y_{it}}{X_{ikt}} &= V_{ikt} : k = 1, 2, \dots, J_i \, ; \, t = 1, \dots, T \\
\frac{\partial \ln Y_{it}}{\partial \ln X_{ikt}} &= \frac{1}{(1 - \ell_{it})} \frac{V_{ikt} X_{ikt}}{Y_{it} P_{it}(Y_t)} = \mu_{it} s_{ikt}, \tag{23}
\end{aligned}
$$

where s_{ikt} denotes the share of the cost of input k in the total production value of firm i, or $s_{ikt} \equiv V_{ikt} X_{ikt} / [Y_{it} P_{it}(Y_t)]$, so that firm i's total (factor) input share can be written as:

$$s_{it} = \sum_{k=1}^{J_i} s_{ikt} = \frac{\mathbf{V}'_{it} \mathbf{X}_{it}}{Y_{it} P_{it}(Y_t)}. \tag{24}$$

Hence, following Ohinata and Plasmans (2002), firm i's total input share is found to be equal to the inverse of its *average markup* at period t, since the latter can be defined as the profit ratio or the ratio of firm i's output price over its average (production) cost at that period, or:

$$\mu_{it}^a \equiv \frac{P_{it}(Y_t)}{AC_{it}} \tag{25}$$

with the average cost being defined as $AC_{it} \equiv \frac{TC_{it}}{Y_{it}} = \frac{\mathbf{V}'_{it} \mathbf{X}_{it}}{Y_{it}}$. Equation (23) says that the output elasticity of any individual input k equals the markup times the share of input k in the total production value of firm i.

The returns to scale parameter θ_{it} measures the responsiveness of output to an increase in all firm i's inputs by a scalar factor λ at period t. Under the homogeneity assumption of production function (14) we have that $F(\lambda \mathbf{X}_{it}) = \lambda^{\theta_{it}} F(\mathbf{X}_{it})$ with $0 < \theta_{it} < \infty$, where $\theta_{it} = 1$ denotes constant returns to scale, $\theta_{it} > 1$ increasing returns to scale, and $\theta_{it} < 1$ decreasing returns to scale.

The time-varying, input-dependent returns to scale parameter, expressed as an elasticity of scale, θ_{it}, is defined as follows (see, e.g., Chambers (1988)):

$$\theta_{it} \equiv \frac{\partial \ln F(\lambda \mathbf{X}_{it})}{\partial \ln \lambda}|_{\lambda=1} = \frac{\partial F(\lambda \mathbf{X}_{it})}{\partial \lambda} \cdot \frac{\lambda}{F(\lambda \mathbf{X}_{it})}|_{\lambda=1}. \tag{26}$$

Hence, under constant returns to scale, $\frac{\partial F(\lambda \mathbf{X}_{it})}{\partial \lambda} = F(\mathbf{X}_{it})$ and $\frac{\lambda}{F(\lambda \mathbf{X}_{it})} = \frac{1}{F(\lambda \mathbf{X}_{it})}$, or (26) implies $\theta_{it} = 1$. By analogous reasoning, we find variable returns to scale implying $\theta_{it} \neq 1$. Since the elasticity of scale θ_{it} is equal to the sum of all output elasticities with respect to inputs given by the sum of equation (23) over all inputs, we can directly express this time-varying, input-dependent elasticity of scale θ_{it} in (26) as the sum over all partial elasticities of scale θ_{ikt}:

$$\theta_{it} \equiv \frac{\partial \ln F(\lambda \mathbf{X}_{it})}{\partial \ln \lambda}|_{\lambda=1} = \sum_{k=1}^{J_i} \frac{\partial Y_{it}}{\partial X_{ikt}} \frac{X_{ikt}}{Y_{it}} = \sum_{k=1}^{J_i} \theta_{ikt}, \tag{27}$$

so that, using the first part of the last equality in (23) and taking account of (16), (24), and (25), the time-varying markup in (21) can be rewritten as the ratio between the time-varying, input-dependent elasticity of scale and the total input share (the inverse average markup):

$$\mu_{it} = \frac{Y_{it} P_{it}(Y_t)}{\mathbf{V}'_{it} \mathbf{X}_{it}} \theta_{it} = \frac{\theta_{it}}{s_{it}} = \mu_{it}^a \theta_{it}. \tag{28}$$

There are two important features of the markup involved in (28). First, it allows for time-varying returns to scale. Under constant returns to scale and constant markups, equation (28) is equivalent to the measure proposed by Hall (1988). However, the assumption of the constant (or non-variable) returns to scale restriction is a strong one that has received criticism from many authors (e.g. Bresnahan (1988), Hylleberg and Jorgenson (1988), Chirinko and Fazzari (1994), Klette (1999), Martins and Scarpetta (1999) and Aghion *et al.* (2006)). Second, the markup measure in equation (28) is allowed to vary over time. There are several possible factors that may cause cyclical behavior of markups. Hall (1986) originally suggested that capacity utilization fluctuations are closely linked to markup levels. Domowitz *et al.* (1988) found that markups are more pro-cyclical in concentrated than in less concentrated US industries. Shapiro (1988) notes that demand elasticities might affect markups. Morrison (1994) takes into account a number of factors (economies of scale, utilization, unemployment, import prices) and finds that estimated markups tend to increase over time and appear to be cyclical.

In addition, Chirinko and Fazzari (1994) find a strong correlation between economies of scale and markups, which is obviously also implied by (28). Several studies also relate markups to business cycles (e.g., Wu and Zhang (2000) and Bloch and Olive (2001)). Although it is realistic to allow for dynamic effects in competition, one should be wary of the effect of business cycles on the markup since, as will be illustrated later, it may not reflect changes in competition. This is one of the reasons we will also consider an alternative measure of competition. The second reason is that the markup may not be able to handle the dynamic effects heterogenous efficiency has on competition. Thus although the markup measure accurately reflects firm's profits, its relation to competition is less clear-cut.

B Bargaining model

This Appendix provides the solution of Nash bargaining model and the derivation of labor elasticity.

The solution to the bargaining problem:

$$\max_{W_{it}, L_{it}, K_{it}, M_{it}} \left[L_{it}(W_{it} - \overline{W}_{it}) \right]^{\phi_{it}} \left[P_{it}(Y_t)Y_{it} - W_{it}L_{it} - R_{it}K_{it} - Z_{it}M_{it} \right]^{1-\phi_{it}}$$

is obtained by maximizing with respect to employment and to wage, and then combining the two FOCs. The FOC for employment gives the following results:

$$\frac{\partial \left[L_{it}(W_{it} - \overline{W}_{it}) \right]^{\phi_{it}} (P_{it}(Y_t)Y_{it} - W_{it}L_{it} - R_{it}K_{it} - Z_{it}M_{it})^{1-\phi_{it}}}{\partial L_{it}} = 0 \quad (29)$$

$$\phi_{it}L_{it}^{\phi_{it}-1}(W_{it} - \overline{W}_{it})^{\phi_{it}}(P_{it}(Y_t)Y_{it} - W_{it}L_{it} - R_{it}K_{it} - Z_{it}M_{it})^{1-\phi_{it}} =$$

$$= (1-\phi_{it})(P_{it}(Y_t)Y_{it} - W_{it}L_{it} - R_{it}K_{it} - Z_{it}M_{it})^{-\phi_{it}}[L_{it}(W_{it} - \overline{W}_{it})]^{\phi_{it}}\left(W_{it} - \frac{\partial P_{it}(Y_t)Y_{it}}{\partial L_{it}} \right)$$

$$\phi_{it}L_{it}^{\phi_{it}-1}(P_{it}(Y_t)Y_{it} - W_{it}L_{it} - R_{it}K_{it} - Z_{it}M_{it}) = (1-\phi_{it})[L_{it}]^{\phi_{it}}\left(W_{it} - \frac{\partial P_{it}(Y_t)Y_{it}}{\partial L_{it}} \right)$$

$$\frac{\phi_{it}}{L_{it}}(P_{it}(Y_t)Y_{it} - W_{it}L_{it} - R_{it}K_{it} - Z_{it}M_{it}) = (1-\phi_{it})\left(W_{it} - \frac{\partial P_{it}(Y_t)Y_{it}}{\partial L_{it}} \right)$$

$$-\phi_{it}W_{it} + \frac{\phi_{it}}{L_{it}}(P_{it}(Y_t)Y_{it} - R_{it}K_{it} - Z_{it}M_{it}) = W_{it} - \phi_{it}W_{it} - (1-\phi_{it})\frac{\partial P_{it}(Y_t)Y_{it}}{\partial L_{it}}$$

$$W_{it} = (1 - \phi_{it})\frac{\partial P_{it}(Y_t)Y_{it}}{\partial L_{it}} + \frac{\phi_{it}}{L_{it}}(P_{it}(Y_t)Y_{it} - R_{it}K_{it} - Z_{it}M_{it})$$

$$W_{it} = \frac{\partial P_{it}(Y_t)Y_{it}}{\partial L_{it}} - \phi_{it}\frac{\partial P_{it}(Y_t)Y_{it}}{\partial L_{it}}\cdot\frac{L_{it}}{L_{it}} + \frac{\phi_{it}}{L_{it}}P_{it}(Y_t)Y_{it} - \frac{\phi_{it}}{L_{it}}R_{it}K_{it} - \frac{\phi_{it}}{L_{it}}Z_{it}M_{it}$$

$$W_{it} = \frac{\partial P_{it}(Y_t)Y_{it}}{\partial L_{it}} + \frac{\phi_{it}}{L_{it}}\left(P_{it}(Y_t)Y_{it} - R_{it}K_{it} - Z_{it}M_{it} - \frac{\partial P_{it}(Y_t)Y_{it}}{\partial L_{it}}\cdot L_{it}\right)$$
$$(30)$$

defining $\frac{\partial P_{it}(Y_t)Y_{it}}{\partial L_{it}} \equiv r_{iLt}$, we can rewrite equation (30) as:

$$W_{it} = r_{iLt} + \frac{\phi_{it}}{L_{it}}\left(P_{it}(Y_t)Y_{it} - R_{it}K_{it} - Z_{it}M_{it} - r_{iLt}\cdot L_{it}\right) \qquad (31)$$

Maximizing with respect to wage leads to:

$$\frac{\partial\left[L_{it}(W_{it} - \overline{W}_{it})\right]^{\phi_{it}}(P_{it}(Y_t)Y_{it} - W_{it}L_{it} - R_{it}K_{it} - Z_{it}M_{it})^{1-\phi_{it}}}{\partial W_{it}} = 0 \quad (32)$$

$$L_{it}^{\phi_{it}}\phi_{it}(W_{it} - \overline{W}_{it})^{\phi_{it}-1}(P_{it}(Y_t)Y_{it} - W_{it}L_{it} - R_{it}K_{it} - Z_{it}M_{it})^{1-\phi_{it}} +$$

$$+ L_{it}^{\phi_{it}}(W_{it} - \overline{W}_{it})^{\phi_{it}}(1-\phi_{it})(P_{it}(Y_t)Y_{it} - W_{it}L_{it} - R_{it}K_{it} - Z_{it}M_{it})^{-\phi_{it}}\cdot(-L_{it}) = 0$$

$$L_{it}^{\phi_{it}}\phi_{it}(W_{it} - \overline{W}_{it})^{\phi_{it}-1}(P_{it}(Y_t)Y_{it} - W_{it}L_{it} - R_{it}K_{it} - Z_{it}M_{it})^{1-\phi_{it}} =$$

$$= L_{it}^{\phi_{it}}(W_{it} - \overline{W}_{it})^{\phi_{it}}(1-\phi_{it})(P_{it}(Y_t)Y_{it} - W_{it}L_{it} - R_{it}K_{it} - Z_{it}M_{it})^{-\phi_{it}}\cdot L_{it}$$

$$\phi_{it}(W_{it} - \overline{W}_{it})^{-1}(P_{it}(Y_t)Y_{it} - W_{it}L_{it} - R_{it}K_{it} - Z_{it}M_{it}) = (1-\phi_{it})L_{it}$$

$$\frac{\phi_{it}(P_{it}(Y_t)Y_{it} - W_{it}L_{it} - R_{it}K_{it} - Z_{it}M_{it})}{L_{it}} = (1-\phi_{it})(W_{it} - \overline{W}_{it})$$

$$-\phi_{it}W_{it} + \frac{\phi_{it}(P_{it}(Y_t)Y_{it} - R_{it}K_{it} - Z_{it}M_{it})}{L_{it}} = W_{it} - \overline{W}_{it} - \phi_{it}W_{it} + \phi_{it}\overline{W}_{it}$$

$$W_{it} = (1 - \phi_{it})\overline{W}_{it} + \frac{\phi_{it}}{L_{it}}(P_{it}(Y_t)Y_{it} - R_{it}K_{it} - Z_{it}M_{it}) \qquad (33)$$

Combining the two FOCs (equation (29) and equation (32)), taking account of the markup (22) in the first section of this Appendix, leads to the reservation wage $\overline{W}_{it}$:

$$
\begin{aligned}
\overline{W}_{it} &= r_{iLt} \equiv \frac{\partial P_{it}(Y_t)Y_{it}}{\partial L_{it}} = \left[P_{it}(Y_t) + Y_{it}\frac{\partial P_{it}(Y_t)}{\partial Y_t}\frac{\partial Y_t}{\partial Y_{it}} \right] \frac{\partial Y_{it}}{\partial L_{it}}, \\
&= P_{it}(Y_t)\left[1 + \frac{\partial P_{it}(Y_t)}{\partial Y_t}\frac{Y_{it}}{P_{it}(Y_t)} \right] \frac{\partial Y_{it}}{\partial L_{it}} = \\
\overline{W}_{it} &= \frac{P_{it}(Y_t)}{\mu_{it}}\frac{\partial Y_{it}}{\partial L_{it}},
\end{aligned}
\tag{34}
$$

Once achieved the optimal reservation wage, we plug expression (34) in expression (32), obtaining:

$$
s_{iLt} = (1 - \phi_{it})\theta_{iLt}\frac{1}{\mu_{it}} + \phi_{it}(1 - s_{iKt} - s_{iMt})
\tag{35}
$$

where s_{iLt}, s_{iKt} and s_{iMt} denote the shares of labour cost in revenue, $\frac{W_{it}L_{it}}{P_{it}(Y_t)Y_{it}}$, capital cost in revenue, $\frac{R_{it}K_{it}}{P_{it}(Y_t)Y_{it}}$, and intermediate goods cost in revenue, $\frac{Z_{it}M_{it}}{P_{it}(Y_t)Y_{it}}$, respectively.

From equation (35) we can explicit the elasticity of labour as:

$$
\theta_{iLt} = \frac{\mu_{it}s_{iLt}}{(1 - \phi_{it})} - \frac{\mu_{it}\phi_{it}(1 - s_{iKt} - s_{iMt})}{(1 - \phi_{it})}.
\tag{36}
$$

equation (35) is derived by plugging expression (34) in expression (33). Multiplying both sides of equation (33) by $\frac{L_{it}}{Y_{it}}$, we have:

$$
\begin{aligned}
\frac{W_{it}L_{it}}{Y_{it}} &= (1 - \phi_{it})\frac{P_{it}(Y_t)}{\mu_{it}}\frac{\partial Y_{it}}{\partial L_{it}}\frac{L_{it}}{Y_{it}} + \frac{\phi_{it}}{L_{it}}P_{it}(Y_t)Y_{it}\frac{L_{it}}{Y_{it}} - \frac{\phi_{it}}{L_{it}}R_{it}K_{it}\frac{L_{it}}{Y_{it}} - \frac{\phi_{it}}{L_{it}}Z_{it}M_{it}\frac{L_{it}}{Y_{it}} \\
&= (1 - \phi_{it})\frac{P_{it}(Y_t)}{\mu_{it}}\theta_{iLt} + \phi_{it}P_{it}(Y_t) - \frac{\phi_{it}}{L_{it}}R_{it}K_{it}\frac{L_{it}}{Y_{it}} - \frac{\phi_{it}}{L_{it}}Z_{it}M_{it}\frac{L_{it}}{Y_{it}} \\
&= (1 - \phi_{it})\frac{P_{it}(Y_t)}{\mu_{it}}\theta_{iLt} + \phi_{it}P_{it}(Y_t)\left[1 - \frac{R_{it}K_{it}}{P_{it}(Y_t)Y_{it}} - \frac{Z_{it}M_{it}}{P_{it}(Y_t)Y_{it}} \right] \\
\frac{W_{it}L_{it}}{P_{it}(Y_t)Y_{it}} &= (1 - \phi_{it})\frac{1}{\mu_{it}}\theta_{iLt} + \phi_{it}\left[1 - \frac{R_{it}K_{it}}{P_{it}(Y_t)Y_{it}} - \frac{Z_{it}M_{it}}{P_{it}(Y_t)Y_{it}} \right] \\
s_{iLt} &= (1 - \phi_{it})\theta_{iLt}\frac{1}{\mu_{it}} + \phi_{it}(1 - s_{iKt} - s_{iMt})
\end{aligned}
$$

from which we obtain

$$\theta_{iLt} = \frac{\mu_{it} s_{iLt}}{(1 - \phi_{it})} - \frac{\mu_{it} \phi_{it}(1 - s_{iKt} - s_{iMt})}{(1 - \phi_{it})}.$$

Substituting $s_{iKt} = \frac{\theta_{it} - \theta_{iLt} - \theta_{iMt}}{\mu_{it}}$ in the last equation, we get:

$$
\begin{aligned}
\theta_{iLt} &= \frac{\mu_{it} s_{iLt}}{(1 - \phi_{it})} - \frac{\mu_{it} \phi_{it}\left(1 - \left[\frac{\theta_{it} - \theta_{iLt} - \theta_{iMt}}{\mu_{it}}\right] - s_{iMt}\right)}{(1 - \phi_{it})} \\
&= \frac{\mu_{it} s_{iLt}}{(1 - \phi_{it})} - \frac{\phi_{it}(\mu_{it} - \theta_{it} + \theta_{iLt})}{(1 - \phi_{it})} \\
&= \frac{\mu_{it} s_{iLt}}{(1 - \phi_{it})} - \left[\frac{\phi_{it}}{(1 - \phi_{it})}\mu_{it} - \frac{\phi_{it}}{(1 - \phi_{it})}\theta_{it} + \frac{\phi_{it}}{(1 - \phi_{it})}\theta_{iLt}\right] \\
\frac{\theta_{iLt}}{(1 - \phi_{it})} &= \frac{\mu_{it} s_{iLt}}{(1 - \phi_{it})} - \frac{\phi_{it}}{(1 - \phi_{it})}\mu_{it} + \frac{\phi_{it}}{(1 - \phi_{it})}\theta_{it}
\end{aligned}
$$

Then, rearranging terms, the elasticity of labor can be expressed in terms of the markup, μ_{it}, the elasticity of scale, θ_{it} and the degree of workers' bargaining power ϕ_{it},

$$\theta_{iLt} = \mu_{it} s_{iLt} - \phi_{it}\mu_{it} + \phi_{it}\theta_{it}.$$

Table 9: Steady-state equilibrium

	FD GMM	*SYS GMM*
$\widehat{\phi}$	0.445	0.869
	(0.023)	(0.180)
$\widehat{\mu}$	0.976	1.012
	(0.013)	(0.016)
$\widehat{\theta}$	0.861	0.506
	(0.011)	(0.011)
Hp: $\phi = 0$		
$\widehat{\mu}$	0.967	1.006
	(0.013)	(0.014)
$\widehat{\theta}$	0.904	0.940
	(0.012)	(0.013)
Time dummies	Yes	
N. firms	7161	

Note: Standard errors in parentheses; sample period 1989-2005; dependent variable: output growth Δy_{it}

C   Tables and Figures

Table 10: TFPG (%) per estimation method

	Hp:	I	II	III
OLS LEVEL	Mean	0.00	0.00	0.00
	Median	0.07	0.08	0.07
FD OLS	Mean	0.00	0.00	0.00
	Median	0.00	0.00	0.00
FD GMM	Mean	0.95	1.00	0.83
	Median	0.93	1.00	0.85

Note: I: $\phi \in (0,1]$; II: $\phi = 0$; III: $\phi = 0, \mu = 1$; TFP percentage growth rates are calculated as residuals.

Table 11: Time trend test (per sector)

Industry	15	17	18	19	20	21	22	24	25	26
z	1.96	-0.82	-2.07	6.10	1.23	-2.74	-1.22	-0.17	-0.25	-0.23
$p-value$	0.050	0.413	0.038	0.000	0.219	0.006	0.221	0.865	0.799	0.819
	27	28	29	30	31	32	33	34	35	36
	-0.28	0.58	-1.03	0.85	0.82	-0.59	-0.71	-1.03	1.65	1.44
	0.780	0.564	0.304	0.396	0.413	0.556	0.476	0.304	0.098	0.150

Figure 1: TFPG per class size
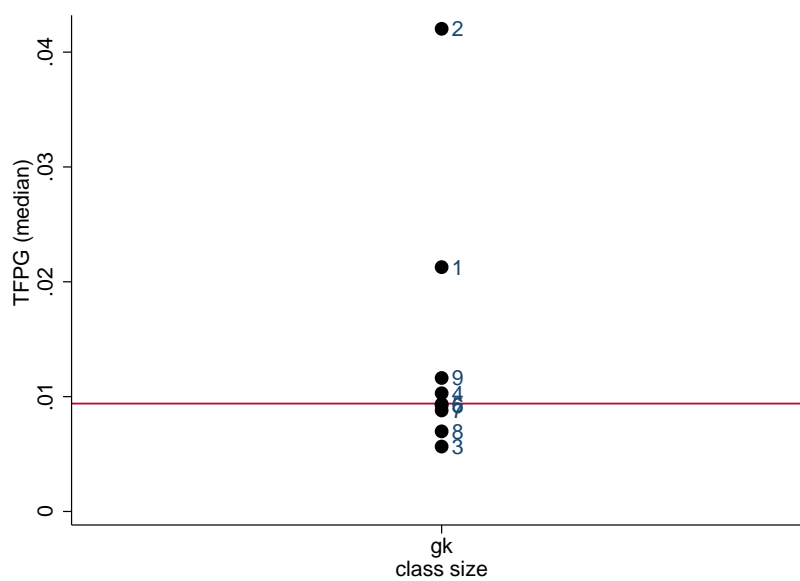
Table 12: NACE 2-digit code and number of firms

Code	Sector	N_j
15-16	Food, beverages, tobacco	2342
17	Textiles	584
18	Wearing apparel	518
19	leather	235
20	wood	666
21	paper products, publishing, printing	436
22	Publishing, printing and reproduction of recorded media	2095
23	coke, refined petroleum products and nuclear fuel	56
24	Chemicals and chemical products	902
25	rubber and plastic products	942
26	other non-metallic mineral products	793
27	Basic metals, Fabricated metal products	256
28	fabricated metal products, except machinery and equipment	3093
29	Machinery and equipment	2362
30	electrical and optical equipment	99
31	electrical machinery and apparatus	617
32	radio, television and communication equipment and apparatus	224
33	medical, precision and optical instruments, watches and clocks	690
34	transport equipment	407
35	Motor vehicles and other	515
36	Other	1106
	Tot	15976

Figure 2: TFPG per sector
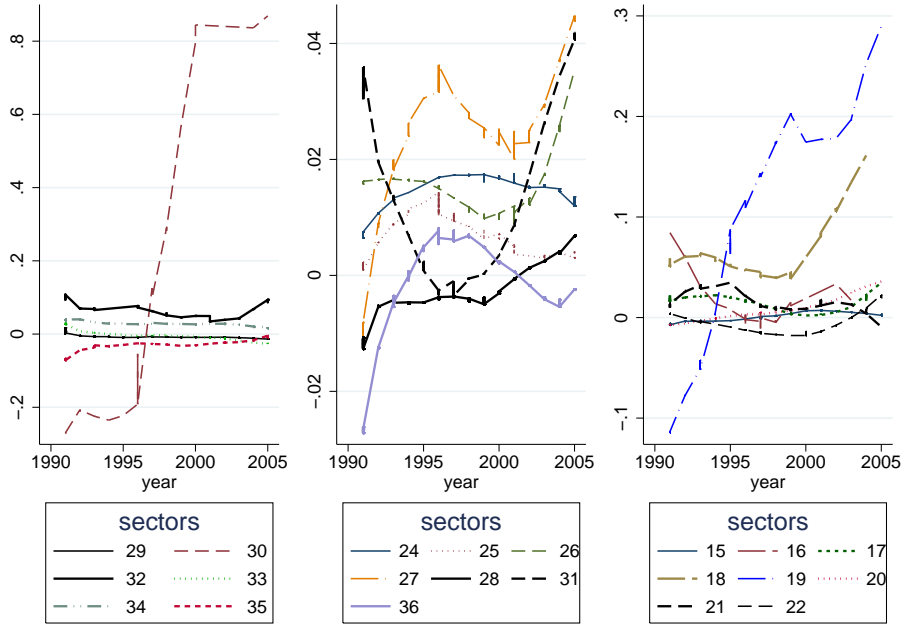
Figure 3: Profit elasticity per sector

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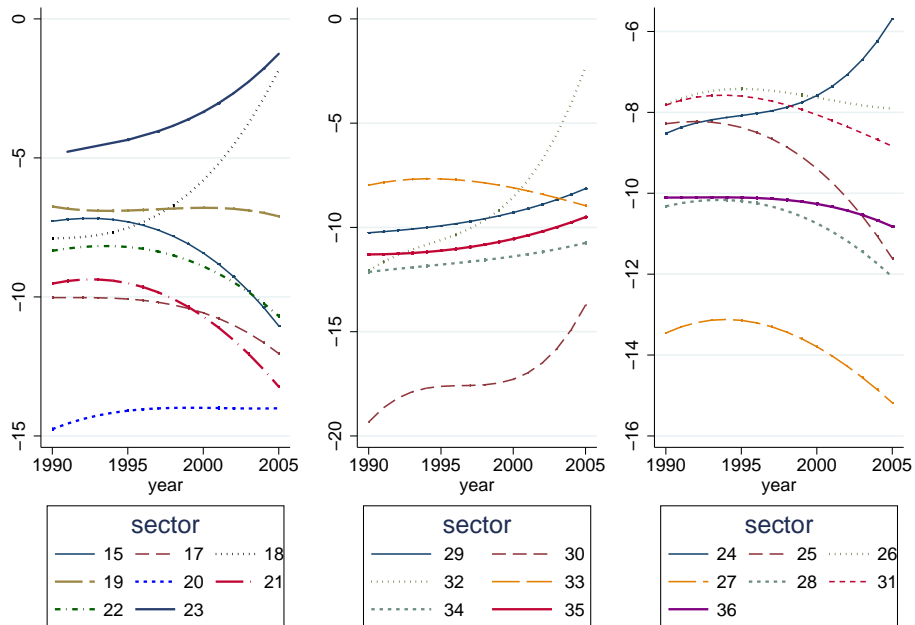
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