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ESTIMATION OF THE CYCLICAL BEHAVIOUR OF MARK-UPS: A TECHNICAL NOTE

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INTRODUCTION

The microeconomic literature provides several possible explanations for the existence of pure profits as a long-run equilibrium configuration. Differences in market power across manufacturing sectors must be due in part to differences in entry conditions into each industry. Traditionally, entry conditions and the resulting market structures have been related to technological conditions, such as economies of scale and scope. Another avenue is the existence of product differentiation. For example, under Chamberlinian monopolistic competition, limited market power can arise from the combination of returns to scale and horizontal product differentiation. More recent research has focused on so-called "vertical" product differentiation where firms are able to influence the perceived quality of their products. In industries where firms engage in such product differentiation, product strategies may be able to influence entry conditions in the market; this influence could generate endogenous sunk costs, *e.g.* large advertising or R&D expenditures (Sutton, 1991). These industries would simply not exist under a perfect competition regime.

Drawing from these microeconomic considerations and following the seminal paper by Bob Hall (1986), there has been a growing interest in the macroeconomic literature on the identification of imperfect competition at the sectoral level by estimating the mark-ups of prices over marginal costs (Hall, 1988; Bils, 1987; Shapiro, 1987; Domowitz, Hubbard and Petersen, 1988; Caballero and Lyons, 1990; Domowitz, 1992; Haskel, Martin and Small, 1995; Roeger, 1995; Beccarello, 1996; Basu and Fernald, 1995 and 1997; Basu, 1995 and 1999).

Together with the estimation of the levels of mark-ups, some of these studies also focus on the behaviour of price-cost margins over the business cycle. However, the theoretical literature does not offer a clear-cut answer as to whether price margins should be pro- or counter-cyclical. This is likely to depend on the specific product market conditions under which each firm operates. For instance, under a regime of monopolistic competition, firms may find it efficient to set counter-cyclical mark-ups. Profit maximisation conditions imply that the mark-up is an inverse function of the elasticity of demand. The latter is likely to be pro-cyclical if, for example, product variety is also pro-cyclical (Weitzman, 1982). Likewise, if entry is possible, increases in demand would induce an increase in the number of firms, thereby raising the degree of competition in the market and lowering price margins (Chatterjee, Cooper and Ravikumar, 1993). A similar outcome would also emerge if firms find it optimal to develop their customer base in periods of up-turns, as suggested by Bils (1987) and by Phelps in his "customer market" model (Phelps, 1994). Certain collusion models also hint at counter-cyclical mark-ups. For example, if firms defecting from a cartel are able to expand their market shares in booms, then the gains from defection may outpace the long-term losses from retaliation by other firms (Rotemberg and Saloner, 1986; Chevalier and Scharfstein, 1996). In contrast, if firms operate in oligopolistic markets with homogeneous goods, the behaviour of each firm depends upon the conjectured responses of all other competitors.[1] Under these conditions, the cyclicality of mark-ups depends on specific market characteristics, such as the existence of capacity constraints. If firms operate under full capacity and, thus, are not able to raise their output in response to a competitor (*i.e.* Cournot competition), then mark-ups are likely to be pro-cyclical because capacity constraints are also pro-cyclical.

Assessing whether the mark-up is pro- or counter-cyclical has important implications for different theories of the business cycle. For example, a counter-cyclical mark-up offers an appealing explanation for the observed pro-cyclicality of real wages (see Rotemberg and Woodford, 1991; Chatterjee *et al.*, 1993; Chevalier and Scharfstein, 1996). In addition, to the extent to which the impact of macroeconomic policies on output and prices depends on the level and cyclicality of mark-ups, identifying mark-up behaviour is important for the design of macroeconomic policies (see for example Silvestre, 1993; Aziz and Leruth, 1997).

Along these lines, in this paper we estimate the cyclical behaviour of mark-up pricing over the business cycle for 36 manufacturing industries in the G5 countries, following an extended version of the Rotemberg and Woodford (1991) approach. The paper relies on OECD estimates (Oliveira Martins, Scarpetta and Pilat, 1996a)[2] of the steady-state mark-up that, in comparison with previous studies, are more in line with microeconomic evidence. Indeed, the estimates based on Hall (1986)'s methodology often lead to an upward bias in price margins and are also likely to lead to a biased and/or inconclusive test as regards cyclicality. For example, firms may react differently to changes in demand when their margins are very high than when they are positive but small.[3] Because the level of the mark-up plays a role for its cyclical behaviour, we believe that our benchmark estimates offer a more solid ground to assess pricing behaviour of firms over the business cycle. In any event, we also assess the sensitivity of the cyclicality of mark-ups to different assumptions concerning the degree of downward rigidity and the elasticity of substitution between factors of production.

The plan of the paper is as follows. In the next section an expression for the cyclical mark-up is derived, which is then used to estimate the fluctuations of cost-price margins across countries and sectors. We then discuss the empirical results and their sensitivity to different parameters' values. The fourth section assesses the impact of the cyclical behaviour of mark-ups on the cyclicality of real wages. The final section provides some concluding remarks.

THE ESTIMATION OF THE TIME-VARYING MARK-UP

In this paper we follow the approach put forward by Rotemberg and Woodford (1991) to estimate the cyclicality of the mark-up.[4] The starting point is the specification of the production function. In order to be coherent with the estimates of the benchmark steady-state mark-up (provided in Oliveira Martins *et al.*, 1996b), we had to use a slightly more complicated specification than in Rotemberg and Woodford (1991). More precisely, we define a production function with three production factors (labour, capital and intermediate inputs) and Hicks-neutral technical progress.[5] In order to keep this specification under a tractable form, without imposing strong separability across production inputs, we assume a two-level production function: capital and labour are nested in a value-added function (G), which is then combined with intermediate inputs using a Leontief specification.[6] Under these assumptions the production function can be written as follows:

$$Q = \Theta \cdot F\left[G\left(K, L - \bar{L}\right), M\right] \qquad (1)$$

where Q, L, K and M are real output, labour, capital and intermediate inputs; Θ is the state of technology at time *t*. We also assume the possibility of downward rigidities in the adjustment of labour inputs that are captured by the amount of fixed labour input, $\bar{L}$. For a profit-maximising firm under imperfect competition, the mark-up of prices over marginal costs (μ) is equal to:

$$\mu_t = \frac{\Theta_t \cdot F_L\left[G\left(K_t, L_t - \bar{L}\right), M\right]}{W_t / P_t} \qquad (2)$$

where P and W are the output price and wages, respectively. F_L is the partial derivative of F with respect to L (or the marginal productivity of labour). By taking a log-linear approximation of equation (2) around a steady-state growth path and doing some algebraic transformations, a relation for the time-varying mark-up can be derived as follows (details are given in the annex):

$$\begin{aligned} \Delta \log \mu = {} & (\Delta q + \Delta p) - \Delta w - \left[\left(\Delta p_G + \Delta g\right) - \left(\Delta p_M + \Delta m\right)\right] \cdot \bar{\mu} \cdot s_M \; + \\ & + \left(\frac{1}{\sigma_G} \cdot \frac{s_K}{s_L + s_k} - \mu \cdot s_K\right) \cdot \Delta k + \left(\frac{1}{\sigma_G} \cdot \frac{s_K}{s_L + s_K} \cdot \frac{L}{L - \bar{L}} + \bar{\mu} \cdot s_L\right) \cdot \Delta l - \bar{\mu} \cdot s_M \cdot \Delta m \end{aligned} \qquad (3)$$

where time indices are omitted and lower case letters denote natural logs and Δ stands for first-differences; p_G and p_M are the prices of value-added and intermediate inputs, respectively; $\bar{\mu}$ is the steady-state mark-up. The coefficients s_L, s_K and s_M are the shares of labour, capital and intermediate inputs in gross output, and σ_G is the elasticity of substitution between capital and labour in the value-added function. The ratio $L/(L-\bar{L})$ in equation (3) can be interpreted as an indicator of the degree of downward rigidities in labour adjustment. It varies from one (no rigidity) to infinity (complete rigidity). Despite its apparent complexity, equation (3) is actually not very demanding in terms of data. Notably, it does not require a price deflator for gross output as the latter only appears in nominal terms. Moreover, under the Leontief specification, the growth rate of the volume of intermediate inputs can be proxied by the growth rate of value added at constant prices. The input shares are directly observable, except the share of capital in gross output s_K, which can be easily derived, consistently with our assumptions, from the Euler equation:

$$\bar{\mu}\cdot s_L\cdot\frac{L-\bar{L}}{L}+\bar{\mu}\cdot s_K+\bar{\mu}\cdot s_M=1 \qquad (4)$$

In our baseline case, we assume the absence of downward rigidities (*i.e.*, $\bar{L}=0$) and a Cobb-Douglas function combining capital and labour (*i.e.* $\sigma_G = 1$). A sensitivity analysis, provided below, tests for the robustness of the results to changes in these baseline assumptions.

EMPIRICAL RESULTS

The results are presented in Table 1.[7] For each country, the first column displays the level of the mark-up by sector (derived from previous OECD estimates). The second column shows the correlation between the logarithmic deviation of the mark-up from its steady-state value and a sectoral cyclical variable. The empirical literature has used different proxies for capturing the cyclical variation of product demand at either the aggregate or the sectoral level. For example, Haskel *et al.* (1995) used aggregate unemployment and capacity utilisation, while Bils (1987) used sectoral employment. In this paper we use deviations of industry output from its long-term trend. The trend output was obtained through a smoothing of the observed output, based on the Hodrick-Prescott filter.[8]

A first observation is that most of the statistically significant correlations imply a counter-cyclical behaviour of mark-ups. This is in line with evidence from other papers (*e.g.* Rotemberg and Woodford, 1991; Bils, 1987; Galeotti and Schiantarelli, 1998; Linnemann, 1999). As an aside, the cross-country comparison of the sectoral mark-ups supports the view that persistent profit margins exist in many manufacturing sectors. This may be due to the presence of entry barriers,

Table 1. **Mark-ups in the G5 countries: levels and correlation with the cycle, 1970-92**

ISIC sectors	France		Germany		Japan		United Kingdom		United States	
	μ[1]	Cycl.[2]	μ[1]	Cycl.[2]	μ[1]	Cycl.[2]	μ[1]	Cycl.[2]	μ[1]	Cycl.[2]
Food products	1.11		1.12	–0.56	1.32		1.20	–0.38	1.05	
Textiles	1.10		1.15	–0.44	1.19	–0.44	1.03		1.08	
Wearing apparel	1.15		1.11	–0.58	. .	. .	1.03		1.10	–0.51
Leather products	1.11		1.18	–0.54	. .	. .	1.06		1.08	–0.43
Footwear	1.13		. .	. .	. .	. .	1.04		1.08	
Wood products	1.15		1.20		. .	. .	1.18		1.22	0.54
Furniture	1.21		1.15	–0.38	1.25		1.19		1.06	–0.54
Printing and publishing	1.24	–0.48	1.09	–0.48	1.10		1.09	–0.43	1.19	–0.53
Plastic products	. .	. .	. .	. .	1.15	–0.49	. .	. .	1.07	–0.55
Non-metal products	1.24		1.26		1.26		1.15		1.18	
Metal products	1.18	0.40	1.20	–0.64	1.11	0.41	1.03		1.09	–0.41
Chemical products	1.19		1.24		1.26	–0.79	1.08	–0.59	1.26	–0.71
Machinery and equipment	1.12		1.06	–0.59	1.09		. .	. .	1.06	. .
Motorcycles and bicycles	. .		. .	. .	. .	. .	. .	. .	1.13	–0.41
Professional goods	. .		1.67	–0.42	1.22		1.16		1.09	–0.51
Other manufacturing	. .		1.30	–0.49	1.38		. .	. .	1.08	–0.44
Beverages	1.68		1.33		1.26		1.54	–0.48	. .	. .
Tobacco	3.12		1.52	–0.51	. .	. .	1.56	–0.45	1.56	–0.58
Paper and pulp	1.13		1.29		1.20		1.05		1.13	
Petroleum refineries	1.19	–0.43	. .	. .	1.04	–0.52	1.07	–0.51	1.03	–0.64
Petroleum and coal products	. .	. .	1.09		1.10	–0.49	1.06	–0.54	1.11	–0.45
Rubber products	1.20	–0.53	. .	. .	1.15	–0.53	. .	. .	. .	. .
Pottery and China	1.29	–0.41	. .	. .	1.22	–0.42	. .	. .	1.09	–0.36
Glass	1.22		1.23	–0.52	1.41		1.06		1.17	–0.66
Iron and steel	1.16	–0.43	1.14		1.19		. .	. .	1.10	
Non-ferrous metals	1.26	–0.51	. .	. .	1.26		1.05		1.14	
Shipbuilding and repair	. .	. .	. .	. .	1.27		. .	. .	. .	. .
Other transport equipment	. .	. .	. .	. .	. .		. .	. .	. .	. .
Industrial chemicals	1.21	–0.45	. .	. .	1.23	–0.60	1.06	–0.51	1.18	
Drugs and medicines	1.04	–0.52	1.45		1.54	–0.77	1.16	–0.54	1.44	–0.65
Office and computing machinery	1.17		1.58	–0.59	1.24		1.47	–0.47	1.54	–0.41
Radio and TV	1.11	–0.54	1.34	–0.67	1.13		1.25	–0.60	1.40	
Electrical apparatus	1.25	–0.48	. .	. .	1.05		. .	. .	. .	. .
Railroad equipment	1.69		. .	. .	. .	. .	. .	. .	. .	. .
Motor vehicles	1.13	–0.45	1.15		1.17	–0.45	. .	. .	1.09	–0.42
Aircraft	1.21		. .	. .	. .	. .	. .	. .	. .	. .

1. The steady-state mark-ups are based on gross output and derived from Oliveira Martins *et al.* (1996b).
2. The correlation between the time-varying mark-up (equation 3 in the text) and the business cycle is estimated under the assumption of no downward labour rigidity and a Cobb-Douglas value added ($\sigma_G = 1$, see text). Only statistically significant mark-ups and correlation coefficients are reported.

Source: OECD-STAN database and authors' calculations.

probably due to sunk costs, that are not eroded by competitive pressures even in the long run.

Another interesting observation emerges from the cross-country comparison of results. While mark-ups are overwhelmingly negatively correlated with the sectoral business cycle, their correlation tends to be stronger in the United States than in the other G5 countries. This fact, taken together with the generally lower level of mark-ups in the US manufacturing sector, lends support to one of the possible interpretation for counter-cyclical mark-ups: the higher degree of competition in the market, driven by *e.g.* higher entry rates, put downward pressure on price margins of incumbent firms.

We test the results obtained in our baseline case against alternative assumptions concerning the elasticity of substitution and the degree of downward rigidities in labour adjustment. In order to simplify the presentation, we only report the estimates for US manufacturing industries but the results for other countries are available upon request. We consider the alternative values of 0.5 and 2 for the elasticity of substitution between capital and labour and the results show that the observed counter-cyclicality of the mark-up is robust with respect to the value of the elasticity of substitution (Table 2). Concerning the degree of downward rigidities, we test for the cases where the fixed amount of labour represents respectively 20 and 40 per cent of total labour input. In line with intuition, more downward rigidity of labour generally increases the negative correlation between mark-up variations and the indicator of the cycle.

IMPLICATIONS OF THE RESULTS FOR THE CYCLICALITY OF REAL WAGES

As pointed out in the introduction, the existence of counter-cyclical mark-ups can provide an appealing interpretation for the observed pro-cyclicality of real wages at the sectoral level. To assess the existence of this link, we compute real product wages for US manufacturing industries using two different price deflators: the observed output price index in a given industry and the output price net of the effects related to the varying mark-up. The variation in the latter deflator (*i.e.* $\Delta p - \Delta \mathrm{Log}\mu$), by definition, should be equal to the variation in marginal costs. We then compute two different series for sectoral real wages in the US economy and calculate the correlation between real wages and the business cycle in each case (Table 3). If the cyclicality of real wages is mainly due to variations in mark-ups, then controlling for the effect of the mark-up should, in principle, remove most of the cyclical component in real wages.

As expected, real wages calculated with the usual price deflator are generally pro-cyclical (Table 3). Only in one sector (wood products) is there a significant negative correlation between real wages and the cycle. But, when real wages net of

Table 2. **Cyclicality of the mark-up: sensitivity analysis for the US manufacturing industries**[1]

ISIC sectors	Elasticity of substitution (K, L) σ = 1			Elasticity of substitution (K, L) σ = 0.5			Elasticity of substitution (K, L) σ = 2		
	Share of fixed labour			Share of fixed labour			Share of fixed labour		
	No rigidity	20%	40%	No rigidity	20%	40%	No rigidity	20%	40%
Food products	–0.31	–0.31	–0.30	–0.32	–0.30	–0.29	–0.30	–0.30	–0.30
Textiles	–0.29	–0.38*	–0.43**	–0.34	–0.41*	–0.41**	–0.43**	–0.32	–0.39*
Wearing apparel	–0.51***	–0.56***	–0.60***	–0.54***	–0.58***	–0.60***	–0.60***	–0.53***	–0.57***
Leather products	–0.43**	–0.52***	–0.61***	–0.47**	–0.61***	–0.66***	–0.61***	–0.46**	–0.51***
Footwear	–0.32	–0.37*	–0.41*	–0.33	–0.36*	–0.35	–0.41*	–0.36*	–0.41*
Wood products	0.54***	0.44**	0.20	0.42**	0.07	–0.35	0.20	0.54***	0.48**
Furniture	–0.54***	–0.59***	–0.59***	–0.57***	–0.56***	–0.52***	–0.59***	–0.57***	–0.61***
Printing and publishing	–0.53***	–0.56***	–0.60***	–0.54***	–0.57***	–0.57***	–0.60***	–0.55***	–0.58***
Plastic products	–0.55***	–0.63***	–0.67***	–0.58***	–0.63***	–0.56***	–0.67***	–0.58***	–0.64***
Non-metal products	–0.28	–0.43**	–0.59***	–0.30	–0.53***	–0.65***	–0.59***	–0.35*	–0.46**
Metal products	–0.41**	–0.48**	–0.51***	–0.46**	–0.50**	–0.50***	–0.51***	–0.43**	–0.48**
Chemical products	–0.71***	–0.69***	–0.65***	–0.65***	–0.60***	–0.52***	–0.65***	–0.72***	–0.71***
Machinery and equipment	–0.20	–0.33	–0.46**	–0.26	–0.44**	–0.56***	–0.46**	–0.25	–0.34
Motorcycles and bicycles	–0.41*	–0.47**	–0.55***	–0.43**	–0.54***	–0.64***	–0.55***	–0.43**	–0.47**
Professional goods	–0.51***	–0.55***	–0.59***	–0.53***	–0.58***	–0.59***	–0.59***	–0.52***	–0.56***
Other manufacturing	–0.44**	–0.50***	–0.57***	–0.51***	–0.57***	–0.63***	–0.57***	–0.44**	–0.49**
Beverages	..	..	..	..	..	..	..	..	..
Tobacco	–0.58***	–0.59***	–0.59***	–0.54***	–0.53***	–0.52***	–0.59***	–0.61***	–0.61***
Paper and pulp	0.06	–0.03	–0.16	–0.04	–0.20	–0.34	–0.16	0.07	0.00
Petroleum refineries	–0.64***	–0.64***	–0.63***	–0.63***	–0.61***	–0.55***	–0.63***	–0.64***	–0.64***
Petroleum and coal products	–0.45**	–0.48**	–0.51***	–0.49**	–0.52***	–0.51**	–0.51***	–0.43**	–0.46**
Rubber products	..	..	..	..	..	..	..	..	..
Pottery and China	–0.36*	–0.53***	–0.64***	–0.30	–0.58***	–0.62***	–0.64***	–0.48**	–0.57***
Glass	–0.66***	–0.70***	–0.72***	–0.66***	–0.72***	–0.69***	–0.72***	–0.68***	–0.70***
Iron and steel	0.19	0.03	–0.18	0.15	–0.16	–0.48**	–0.18	0.13	0.02
Non-ferrous metals	0.12	0.04	–0.09	0.00	–0.17	–0.40*	–0.09	0.13	0.08
Shipbuilding and repair	..	..	..	..	..	..	..	..	..
Other transport equipment	..	..	..	..	..	..	..	..	..
Industrial chemicals	–0.04	–0.09	–0.16	–0.11	–0.20	–0.32	–0.16	–0.03	–0.07
Drugs and medicines	–0.65***	–0.64***	–0.63***	–0.60***	–0.57***	–0.53***	–0.63***	–0.68***	–0.67***
Office and computing machinery	–0.41*	–0.48**	–0.56***	–0.46**	–0.56***	–0.61***	–0.56***	–0.41**	–0.47**

Table 2. **Cyclicality of the mark-up: sensitivity analysis for the US manufacturing industries**[1] (*cont.*)

ISIC sectors	Elasticity of substitution (K, L) σ = 1			Elasticity of substitution (K, L) σ = 0.5			Elasticity of substitution (K, L) σ = 2		
	Share of fixed labour			Share of fixed labour			Share of fixed labour		
	No rigidity	20%	40%	No rigidity	20%	40%	No rigidity	20%	40%
Radio and TV	–0.20	–0.10	0.07	0.09	0.23	0.26	0.07	–0.28	–0.22
Electrical apparatus	. .	. .	. .	. .	. .	. .	. .	. .	. .
Railroad equipment	. .	. .	. .	. .	. .	. .	. .	. .	. .
Motor vehicles	–0.42**	–0.53***	–0.62***	–0.44**	–0.59***	–0.63***	–0.62***	–0.46**	–0.53***
Aircraft	. .	. .	. .	. .	. .	. .	. .	. .	. .

1. For the period 1970-92. The variable mark-ups are based on equation 3 in the text. The columns display the correlation between the variable mark-up and the cycle. Correlation coefficients were calculated only for those sectors for which the estimates of the steady-state mark-ups were available.

* Statistically significant at the 10 per cent level.

** At the 5 per cent level.

*** At the 1 per cent level.

Source: Authors' calculations.

Table 3. **Mark-ups and the pro-cyclicality of real wages, US manufacturing industries**[1]

ISIC sectors	Correlation between real product wages and the cycle[1]	
	Wages deflated by sectoral output prices	Wages deflated by sectoral output prices adjusted for mark-ups
Food products	0.29	–0.01
Textiles	0.19	–0.04
Wearing apparel	0.50**	0.09
Leather products	0.44**	0.27
Footwear	0.37*	0.27
Wood products	–0.59***	–0.47**
Furniture	0.43**	–0.18
Printing and publishing	0.53***	0.13
Plastic products	0.43**	0.05
Non-metal products	0.28	0.05
Metal products	0.27	–0.05
Chemical products	0.62***	–0.06
Machinery and equipment	0.06	–0.45**
Motorcycles and bicycles	0.34	–0.05
Professional goods	0.49**	0.22
Other manufacturing	0.46**	0.24
Beverages	. .	. .
Tobacco	0.49**	–0.07
Paper and pulp	–0.19	–0.38*
Petroleum refineries	0.64***	0.31
Petroleum and coal products	0.32	–0.19
Rubber products	. .	. .
Pottery and China	0.31	0.17
Glass	0.59***	–0.23
Iron and steel	–0.08	0.26
Non-ferrous metals	–0.07	0.11
Shipbuilding and repair	. .	. .
Other transport equipment	. .	. .
Industrial chemicals	0.08	0.10
Drugs and medicines	0.63***	0.03
Office and computing machinery	0.33	–0.03
Radio and TV	0.53***	0.57***
Electrical apparatus	. .	. .
Railroad equipment	. .	. .
Motor vehicles	0.43**	0.04
Aircraft	. .	. .

1. For the period 1970-92.
* Statistically significant at the 10 per cent level.
** At the 5 per cent level.
*** At the 1 per cent level.
Source: Authors' calculations.

the effect of mark-up variations are computed, most of the pro-cyclical behaviour of real wages vanishes, except in one sector (radio and TV). This suggests that the main cause for pro-cyclical real product wages could indeed be the presence of counter-cyclical mark-ups. With the usual caveats related to the imperfection of data and estimating assumptions, our results add to an already large body of literature offering an interesting explanation for a long-standing puzzle of business cycles.

CONCLUSIONS

In this paper, we provide estimates of the cyclical behaviour of price margins across manufacturing industries. The results strongly support the hypothesis of counter-cyclical variations in price margins in most manufacturing industries in the United States and, to a lesser extent, in other G5 countries. This is consistent with a growing body of literature showing that economic booms tend to increase competition or decrease the incentives for collusion, thereby creating downward pressures on price margins. We also show that the assumption concerning the degree of downward rigidities in labour adjustment tend to reinforce the estimated counter-cyclicality of the mark-up. The finding of counter-cyclical mark-ups by sector offers an appealing and plausible explanation for the observed pro-cyclicality of real wages. Indeed, the latter seems to vanish once the price deflator used to compute real wages is corrected for cyclical variations in price margins. Overall, further research is needed in order to better understand the relationship between industry price behaviour and market characteristics; a research that calls for a higher level of integration between macroeconomic and industrial organisation theories.

NOTES

1. It can be demonstrated that, in this case, the profit-maximising mark-up level of a firm is a function of the degree of concentration in the market and the firm's conjecture of the output responses of other firms to a change in its output.
2. See Oliveira Martins, Scarpetta and Pilat (1996b) for a detailed presentation and results of the estimation of the mark-up ratio for 36 manufacturing industries and 14 OECD countries. This Working Paper can be downloaded from *www.oecd.org\eco*
3. See for example, the comments of Valérie Ramey on the analysis of the cyclical behaviour of mark-ups presented in Rotemberg and Woodford (1991).
4. This approach provides a second-order approximation of the production function and therefore seems more reliable than the usual methods that rely on a first-order Taylor approximation. Indeed, since the time variation of the mark-up is a second-order effect it also requires a full second-order approximation of the production function (see also Morrison, 1992).
5. Rotemberg and Woodford (1991) defined a production function with capital, labour only and a labour-augmenting technology.
6. This assumption is usual in the literature and does not seem overly stringent. Using a generalisation of the Rotemberg and Woodford's approach, Linnemann (1999) provided numerical simulations suggesting that the type of cyclical behaviour of the mark-up is relatively robust to different values of the elasticity of substitution between value added and intermediate inputs.
7. The version of the OECD STAN data base used in this study (OECD, 1996) covers 21 OECD Member countries and 36 manufacturing sectors (at the 3-4 ISIC digit-level) for the period 1970-1994. STAN provides data on the following variables: production, value added in current and constant prices, gross fixed capital formation, employment (number of persons engaged), labour compensation, exports and imports. Capital stocks were estimated by the OECD Directorate for Science, Industry and Technology and are available upon request.
8. Since we use annual data, the weighting factor for the filter is set at 100.

Annex

MATHEMATICAL DERIVATIONS

The derivation of the mark-up variations proceeds as follows. Recalling that under imperfect competition the mark-up of prices over marginal costs is:

$$\mu_t = \frac{\Theta_t \cdot F_L\left[G\left(K_t, L_t - \bar{L}\right), M\right]}{W_t / P_t} = \frac{\Theta_t \cdot F_G \cdot G_L}{W_t / P_t} \tag{A1}$$

assuming that W_t and Θ_t have the same trend growth rates, taking the total differential, dividing by (μ.W/P) and simplifying (time indices are omitted):

$$\Delta \log \mu = \theta - (\Delta w - \Delta p) + \frac{1}{F_G} \cdot \left(F_{GG}\, dG + F_{GM}\, dM\right) + \frac{1}{F_G}\left(G_{LL}\, dL + G_{LK}\, dK\right) \tag{A2}$$

where lower case letters denote natural logs and Δ stands for the first-difference; θ is the rate of Hicks-neutral technical progress (*i.e.* $\theta_t = \Delta \log \Theta_t$).

By using the following relations:

- At the first-level the elasticity of substitution between capital and labour can be written as $\sigma_G = G_L \cdot G_K / G_{KL} \cdot G$; and the elasticity between value-added and intermediate inputs as $\sigma = F_G \cdot F_M / F_{GM} \cdot F$.
- Using the separability properties and by differentiating the Euler equation of F and G, with respect to G and L, respectively, yields: $F_{GG} = -F_{GM} \cdot M / G$ and $G_{LL} = -G_{KL} \cdot K / (L - \bar{L})$.
- From the first-order conditions: $\frac{F_M \cdot M}{F} = \bar{\mu} \cdot s_M$ and $\frac{G_K \cdot K}{G} = \frac{s_K}{s_L + s_K}$.

The above equation (A2) can be transformed into the following expression:

$$\begin{aligned}\Delta \log \mu = \theta - {} & (\Delta w - \Delta p) - \frac{1}{\sigma} \cdot \bar{\mu} \cdot s_M \cdot \Delta g + \frac{1}{\sigma} \cdot \bar{\mu} \cdot s_M \cdot \Delta m \\ & - \frac{1}{\sigma_G} \cdot \frac{s_K}{s_L + s_K} \cdot \frac{L}{L - \bar{L}} \cdot \Delta l + \frac{1}{\sigma_G} \cdot \frac{s_K}{s_L + s_K} \cdot \Delta k\end{aligned} \tag{A3}$$

Finally, the unobservable productivity term θ can be derived by totally differentiating the production function (equation 1 in the text) and recalling that $\frac{F_K \cdot K}{Q} = \frac{\bar{\mu} \cdot s_K}{\theta}$; $\frac{F_L \cdot L}{Q} = \frac{\bar{\mu} \cdot s_L}{\theta}$; and $\frac{F_M \cdot M}{Q} = \frac{\bar{\mu} \cdot s_M}{\theta}$ which yields:

$$\Delta q = \theta + \bar{\mu} \cdot s_K \cdot \Delta k + \bar{\mu} \cdot s_L \cdot \Delta l + \bar{\mu} \cdot s_M \cdot \Delta m \tag{A4}$$

By subtracting (A4) from (A3) and re-arranging one gets:

$$\begin{aligned}\Delta \log \mu = (\Delta q + \Delta p) - \Delta w - \frac{1}{\sigma} \cdot \bar{\mu} \cdot s_M \cdot (\Delta m - \Delta g) + \left(\frac{1}{\sigma_G} \cdot \frac{s_K}{s_L + s_k} - \mu \cdot s_K \right) \cdot \Delta k \\ + \left(\frac{1}{\sigma_G} \cdot \frac{s_K}{s_L + s_K} \cdot \frac{L}{L - \bar{L}} + \bar{\mu} \cdot s_L \right) \cdot \Delta l - \bar{\mu} \cdot s_M \cdot \Delta m\end{aligned} \tag{A5}$$

It is noteworthy that the above equation does not require the volume of gross output, but only its growth rate in nominal terms. This advantage overcomes the lack output prices for a number of sectors/countries. However, the equation still requires the volume for both value added and intermediate inputs. While the former is usually provided in industrial statistics, the latter was not available in the database used in this study. In order to solve this data constraint, an additional assumption was required. We considered here the special case of a Leontief function between value added and intermediate inputs. In that case, under cost minimisation, the volume of intermediate inputs can be identified with the volume of value added, *i.e.* $\Delta m = \Delta g$. This simplifying assumption does not seem an excessively stringent one. Nonetheless, an additional problem arises. By inspecting equation (A5), it can be readily seen that if $\sigma = 0$ (the Leontief specification), the term:

$$\frac{1}{\sigma} \cdot \bar{\mu} \cdot s_M \cdot (\Delta m - \Delta g) \approx \frac{0}{0} \tag{A6}$$

is not determined. In order to solve this problem, let us consider the definition of the two-factor elasticity of substitution $\sigma = (\Delta g - \Delta m) / (\Delta p_M - \Delta p_G)$. By replacing this expression into (A6) and noting that under the Leontief assumption $\Delta p_G - \Delta p_M = (\Delta p_G + \Delta g) - (\Delta p_M + \Delta m)$, the undetermined term above can be identified as:

$$\frac{1}{\sigma} \cdot \bar{\mu} \cdot s_M \cdot (\Delta m - \Delta g) = [(\Delta p_G + \Delta g) - (\Delta p_M + \Delta m)] \cdot \bar{\mu} \cdot s_M \tag{A7}$$

Using this result and substituting it into equation (A5), one finally obtains equation (3) in the main text.

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