1. Introduction

The seminal contribution by De Loecker and Warzynski (2012) has equipped researchers with the ability to estimate time-varying, firm-level price-cost margins. Several papers have then explored the determinants of markups, their evolution and their relationship with productivity, quality and other relevant variables (De Loecker and Goldberg, 2014; Bellone et al., 2016; De Loecker et al., 2016; Caselli et al., 2017).

This paper starts from the observation that, for protracted periods of time, several firms display markups lower than unity, i.e., negative price-cost margins, which we label markdowns. The analysis documents in a robust way the size of this phenomenon using a large sample of French manufacturing firms for the period 1990-2007. To the best of our knowledge, this is the first paper analysing the presence and persistence of negative price-cost margins at the firm level.

This phenomenon can be rationalized in multiple ways. Firms could engage in strategic dumping in order to exploit returns to scale and conquer market shares, especially in the presence of learning effects, or to drive competitors out of business. The ability to sustain temporary losses would then be related to firm size.

Persistent markdowns may also suggest the inability of market selection to push less productive and less successful firms out of the market. For example, a financial system that keeps credit flowing to insolvent borrowers may act as a barrier to market selection (see, for instance, Caballero et al., 2008; Kwon et al., 2015 on Japanese "zombie firms" and Andrews et al., 2016; McGowan et al., 2017 for a discussion of the more recent productivity slowdown in OECD countries due to less efficient market selection). Market selection may also be hindered by government subsidies to firms and sectors facing losses with the purpose to keep them afloat.

Yet another explanation is rooted in the option value approach to investment decisions. Dixit and Pindyck (1994) show that the presence of sunk costs produces a zone of inaction, whereby firms rationally choose to wait and see rather than engage in an investment/disinvestment decision. Moreover, uncertainty reinforces this kind of behaviour by increasing the "value of waiting". Thus, firms may be ready to absorb some losses in order to retain the ability to serve a certain market and make profits once economic conditions improve. In the presence of dynamic demand or learning-by-doing, this would even imply that large numbers of firms may be willing to price below marginal costs for certain periods of time.

Using a formal econometric approach, this paper will investigate the link between variables associated with the above mechanisms and markdowns. This analysis makes it possible to establish additional stylised facts with regards to the persistence of negative price-cost margins and the potential mechanisms behind them.

The paper is organised as follows. Section 2 describes the data and the methodology used to estimate markups. Section 3 presents the empirical analysis: first some stylised facts about markdowns and then results of a regression analysis on the determinants of negative price-cost margins. Section 4 provides some concluding remarks.

2. Data and estimation of markups

2.1. Data sources

We use data on a large sample of French manufacturing firms based on an annual survey (EAE) that gathers information on firms with at least 20 employees. After some basic cleaning, we analyze data for over 35,000 firms covering the period 1990-2007.

The EAE contains information on the value of total sales, capital stock and materials, the number of hours worked by employees, profits, exports and government subsidies as well as the 4-digit industry in which the firm operates. Real values of sales, capital and materials are obtained using 2-digit industry deflators provided by the French national statistical office (INSEE). INSEE also compiles industry depreciation rates.

2.2. Estimation of markups

To consistently estimate markups we follow De Loecker and Warzynski (2012). They derive a simple expression from a firm's cost minimisation problem, assuming that at least one input is adjusted freely (materials), while capital and labour may show frictions in their adjustment. Markups are then given by

$$\mu_{it} = \theta_{it}^{m} \left(\alpha_{it}^{m}\right)^{-1}, \tag{1}$$

where μ_{it} is the markup of firm i at time t, θ_{it}^{m} is the output elasticity of materials (superscript m), and α_{it}^{m} is the revenue share of materials. While it is straightforward to compute the latter from the data, the output elasticity relies on estimates of a production function. We assume a translog specification and check the robustness of our results using Cobb-Douglas. We adopt the estimator proposed by Wooldridge (2009) and implemented in Petrin and Levinsohn (2012). Based on the estimates of the production function, we also compute productivity at the firm-year level.

Since we lack data on firm-level output and input prices (with the exception of labour), we effectively estimate a revenue function rather than a physical production function. De Loecker and Goldberg (2014) show that not controlling for output price heterogeneity may lead to a downward bias in markup estimates, but they do not show unambiguously how results may be biased when both output and input price heterogeneity is not controlled for. Moreover, many firms constantly change their product mix by adding and dropping products, but we estimate aggregate firm-level markups as we lack information at the firm-product level. However, as it is usually assumed that multi-product firms use the same technology to produce a specific product as single-product firms (De Loecker et al., 2016), this should not necessarily lead to any bias. Even though this discussion may imply that our estimates could be biased, the distribution of markups we obtain is in line with that from other studies (De Loecker and Goldberg, 2014; Caselli et al., 2017).

Based on these estimates, we define a markdown when firm i's upper bound of the 95% confidence interval (based on the Delta method) for the markup is below unity. Then we measure the incidence of markdowns as the total number of years in which firm i faces markdowns ($\mu_i^{tot<1}$). The use of a confidence interval to identify markdowns implies a more conservative measure of negative price-cost margins and makes our results more robust.

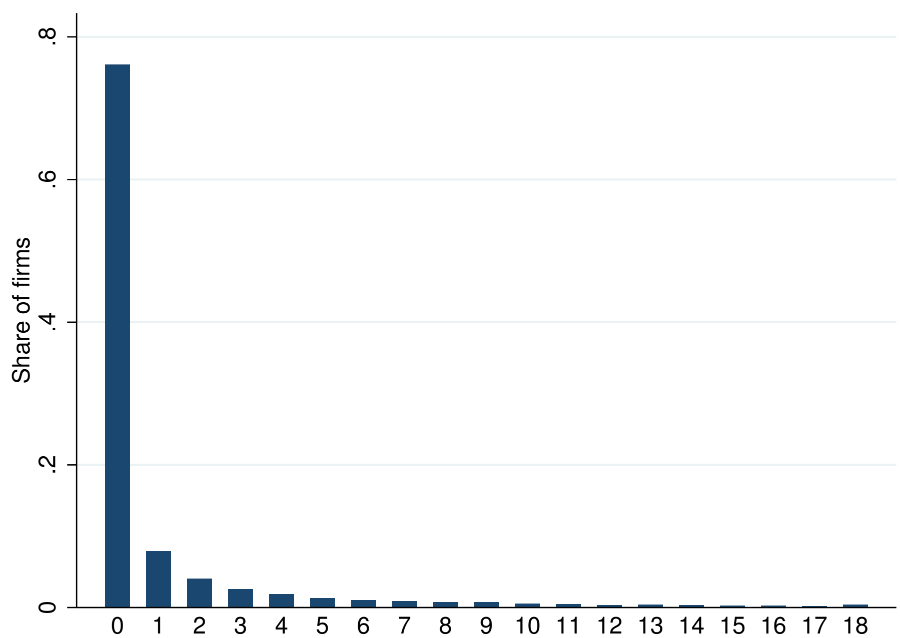
3. Empirical Analysis

3.1. Descriptive statistics

We now provide some descriptive statistics for markups and document the extent to which plants exhibit markdowns.

On average, around 14% of observations in the sample display a negative price-cost margin; the number of observations with markdowns increases after 2000, in line with the evidence of

Figure 1: Share of firms by number of years with markdowns



Source: Own estimations using French manufacturing data from *Enquête Annuelle d'Entreprises* and the WLP estimator of the production function.

diminishing market selection put forward by Berlingieri et al. (2017).[1] Even though other papers do not analyse the presence and persistence of negative price-cost margins, it is possible to deduce that a large number of observations with markdowns is not only a feature of the French manufacturing data but can also be observed for the case of India (De Loecker and Goldberg, 2014; De Loecker et al., 2016) and Mexico (Caselli et al., 2017). In these countries, markdowns account for about 25% to 45% of observations.

Figure 1 shows that almost 25% of firms exhibit markdowns in at least one year, while over 6% of firms display markdowns in at least five years.[2] A similar picture can be shown if, instead of the total number of years in which a firm faces markdowns, we use the maximum number of consecutive markdowns. Indeed, the two measures are highly correlated, with a value of 0.98. This implies that the presence of markdowns within a firm is not a random occurrence due to measurement error, but rather a robust phenomenon.

In Table 1 we compare firms that never exhibit markups lower than unity (Markdown = 0) with those that experience at least one year with markdowns (Markdown = 1) using t-tests and Kolmogorov-Smirnov tests for the differences between the two groups. Firms that exhibit markdowns tend to be larger and employ more workers and capital, while their productivity is significantly lower. While at first sight this result may seem at odds with the literature suggesting that

[1]The percentage of observations exhibiting markdowns reaches 46% when we use a Cobb-Douglas production function.

[2]These numbers increase substantially when we use a Cobb-Douglas production function, going up to 60% and 30% respectively.

Table 1: Descriptive statistics by markdown

	Sales	Labour	Capital	ω_{it}
Markdown = 0	25,128.9	21,6815.4	8,199.2	1.13
Markdown = 1	42,146.8	30,5223.7	12,477.8	0.99
t-test	-11.98	-17.03	-7.62	51.18
(p-value)	(0.00)	(0.00)	(0.00)	(0.00)
K-S test	0.18	0.10	0.12	0.12
(p-value)	(0.00)	(0.00)	(0.00)	(0.00)

Notes: The variables in columns are: sales (1000s euros), labour (number of hours worked), capital stock (1000s Euros), TFP (ω_{it}). The number of observations is 317,102.

larger and more productive firms have higher markups, these are unconditional means and only a more formal analysis, as conducted in the next section, can establish how these variables are related to each other. On the other hand, Table 1 suggests that firms incurring in losses and yet staying in the market are not simply poorly-performing firms, but rather this may be a rational choice of profit-maximising firms facing a negative shock. Moreover, the fact that several firms' characteristics differ depending on whether firms exhibit a markdown in at least one year justifies an econometric model that treats differently the probability of exhibiting a markdown and the extent of such markdowns, as we do in the next section.

3.2. Econometric analysis

Having provided evidence for the presence and persistence of negative price-cost margins in the French manufacturing data, this section turns to a formal econometric analysis to establish some mechanisms related to markdowns.

As we are interested in establishing a set of stylised facts with regards to which variables are potentially correlated with the incidence of negative price-cost margins, the analysis makes use of the cross-section of firms, rather than the panel. Using a cross-section of firms also makes it possible to include in the analysis variables that are time-invariant within a firm. Therefore, we estimate the following equation:

$$\mu_i^{tot<1} = h\left(\gamma + \delta \mathbf{X}_i + \eta_s\right) + \epsilon_i, \tag{2}$$

where $\mu_i^{tot<1}$ is the total number of years in which firm i's upper bound values of markups are lower than unity, $\mathbf{X}_i$ is a vector including all variables of interest, η_s represents three-digit industry fixed effects, function h depends on the underlying model chosen to estimate equation (2) and ϵ_i is the error.

To look at potential mechanisms leading to negative price-cost margins, we include in the vector $\mathbf{X}$ a set of variables associated with the option value approach, strategic dumping, and subsidies. To take into account the option value approach, we need to measure irreversibility and uncertainty. Irreversibility is proxied by a dummy equal to one if a plant belongs to a three-digit industry whose depreciation rate lies below the median (Chirinko and Schaller, 2009). The intuition is that, when firms find it costly to shed capital, they can reduce it via depreciation. This is less likely to occur in industries with low depreciation rates, so that firms in those sectors are more likely to face irreversibility.[3] To measure uncertainty, we use the root-mean-squared error (RMSE) of a

[3] It should be noticed that the parameter on irreversibility cannot be identified directly in equation (2) because it

second-order autoregression of sales (Alesina et al., 2003). This is measured at the firm level and it is invariant over time. The larger a firm is, the longer it can sustain strategic dumping. Thus, we add the time average of real sales as a proxy for firm size. Important or well-connected firms facing persistent losses may receive government subsidies with the purpose to keep them afloat. Therefore, we include the time average of the ratio of government subsidies to sales. Finally, we add time averages of labour, capital and productivity to control for persistent and idiosyncratic productivity shocks at the firm level as well as the total number of years in which a firm appears in the sample (lifespan).

Given that our dependent variable takes non-negative integer values, linear regression is not appropriate (Cameron and Trivedi, 2013), and we turn to count data models. In particular, we estimate equation (2) using Poisson, negative binomial II (NB-II), zero-inflated and hurdle regressions, and we test which model is preferred. All the tests show that the NB-II hurdle model, which combines logit and truncated NB-II regressions, is to be preferred, thus suggesting that zero and positive counts come from separate and potentially independent decision-making processes.

Table 2 reports the estimates of equation (2) based on the logit-truncated NB-II hurdle model and markups estimated either via the translog production function (first two columns) or the Cobb-Douglas production function (last two columns). The table shows two-step block bootstrapped standard errors to obtain unbiased and consistent estimates of the standard errors in the presence of generated variables, such as markups, the measure of uncertainty and productivity (Ashraf and Galor, 2013; Caselli, 2018).

Table 2 shows that the dummy for irreversibility is positive and statistically significant in all regressions. This implies not only that firms in industries with more irreversible investment are more likely to display markdowns in at least one year, but also exhibit a larger number of years with markdowns. When prices fall below marginal costs and selling capital is costly, i.e., investment is irreversible, firms tend to stay in the market waiting for conditions to improve rather than exit.

What is more, the interaction between uncertainty (measured by RMSE sales) and irreversibility is also positive and significant in the logit regressions, while it is not significant in the truncated NB-II regressions. This result suggests that firms facing more irreversible investment coupled with more uncertainty in their sales are more likely to go through at least one year with a markdown, while there is no evidence that they also tend to withstand more years with markups lower than unity. Hence, an uncertain environment magnifies the effect of irreversibility on the tendency of firms to stay in the market and wait for conditions to improve, even though they are incurring in losses.

Larger firms in terms of real sales tend to be more likely to face markdowns in at least one year and to exhibit a larger number of years with markdowns. This result provides some evidence in favour of strategic dumping by firms to exploit returns to scale or to drive competitors out of business. On the other hand, there seems to be a negative relationship between positive productivity shocks and markdowns as firms' margins tend to increase in these cases.

Finally, government subsidies do not seem to be related to the incidence of markdowns, except in the logit regression based on the Cobb-Douglas production function.

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is perfectly collinear with the industry fixed effects η_s. Therefore, in all regressions below we employ the fixed-effects filtered-estimation method by Pesaran and Zhou (2016) to retrieve the estimates of the coefficient on the irreversibility variable.

Table 2: Markdowns, irreversibility and uncertainty

	Translog		Cobb-Douglas	
	Logit	Tr. NB-II	Logit	Tr. NB-II
RMSE sales	0.44***	-0.50***	2.29***	0.18**
	(0.15)	(0.20)	(0.22)	(0.09)
Irreversibility	0.65***	0.20**	6.16***	1.49***
	(0.10)	(0.10)	(0.26)	(0.11)
RMSE sales $\times$ Irreversibility	0.43***	-0.04	0.43*	0.08
	(0.18)	(0.23)	(0.28)	(0.10)
Sales	0.64***	0.51***	4.43***	1.20***
	(0.04)	(0.05)	(0.15)	(0.05)
Labour	-0.47***	-0.34***	-3.13***	-0.75***
	(0.04)	(0.05)	(0.11)	(0.04)
Capital	-0.04**	-0.10***	-0.50***	-0.17***
	(0.02)	(0.03)	(0.04)	(0.02)
Productivity	-0.64***	-0.10	-9.22***	-2.32***
	(0.17)	(0.17)	(0.37)	(0.17)
Subsidies	-0.06	-0.97	1.03***	0.01
	(0.39)	(0.81)	(0.34)	(0.08)
Lifespan	0.04***	0.11***	0.05***	0.11***
	(0.01)	(0.01)	(0.01)	(0.01)
Industry fixed effects	yes	yes	yes	yes
No of obs.	30042	7344	30469	18923
R^2/Pseudo R^2	0.09		0.23	
F-statistics/LR χ^2	6016.65		33671.20	

Notes: The dependent variable is the total number of years with markdowns for each firm. Sales, labour, capital, productivity and the ratio of government subsidies to sales (subsidies) are measured as averages over time within firms. Lifespan in the total number of years in which a firms appears in the sample. Two-step bootstrapped standard errors clustered at the plant level and stratified at the sector level are shown in parentheses (500 repetitions). *, ** and *** indicate coefficients significantly different from zero at the 10%, 5% and 1% level respectively.

4. Conclusion

Recent papers estimating markups and looking at their determinants have disregarded the high incidence of observations with markups lower than unity. A large proportion of firms stay in the market for many years even if they incur in losses. Setting measurement issues aside, not only is this interesting *per se*, but understanding the circumstances in which market selection may not be working fully is also important to study the aggregate dynamics of productivity and growth.

Using a large sample of French manufacturing firms for the period 1990-2007, this paper firstly estimates markups at the firm level and then documents the extent to which firms exhibit what we call markdowns, i.e., price lower than marginal cost. Thus, the main contribution of this paper is to present stylized facts about the presence of negative price-cost margins. Using a formal econometric approach, we also attempt to shed some light on the mechanisms that may be behind this phenomenon. Yet, further work is required to better understand in a causal way its determinants and consequences.

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