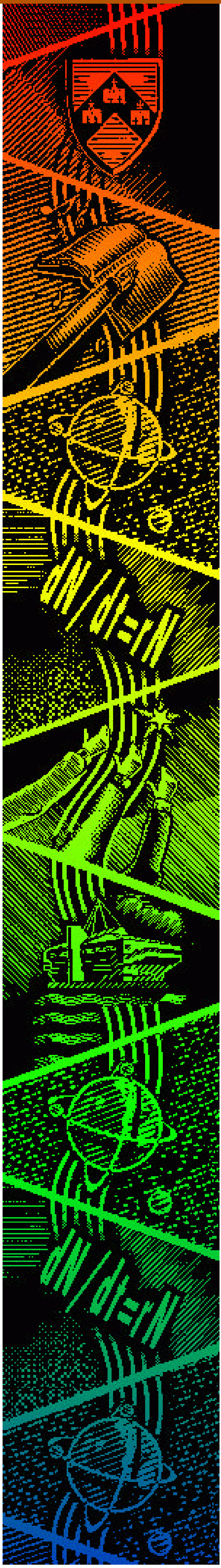

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Technical Efficiency Change and Finance Constraints: An Empirical Analysis for the Italian Manufacturing, 1989-1994

by

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Abstract

The purpose of this paper is to test whether finance constraints create an incentive for debt-constrained firms to improve efficiency along time, using a sample of 1124 firms from the Italian manufacturing over the period 1989-1994. Technical efficiency change indices are derived using a new approach based on the estimation of distance parametric frontiers. These are then regressed on measures of finance constraints to analyze their impact on firms' efficiency growth. The results support the hypothesis that technical efficiency change is affected by the external resources availability; more precisely, once a firm is subject to finance constraints, it has an incentive to improve its technical efficiency over time to guarantee positive profits and gains in productivity.

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1 Introduction

The last twenty years have witnessed a dramatic revival of research on the impact of asymmetric distribution of information among borrowers and lenders on the optimal properties of the competitive equilibrium in the credit market and on firms' capital accumulation process[1]. This interest is due to the path-breaking developments in the economics of information and incentives after the Akerlof's seminal paper (1970) on the potential inefficiencies in trade arising when either of the parties involved has an informational advantage. Thanks to a series of influential papers by Stiglitz and Weiss (1981) and Williamson (1986), the formal apparatus devised to analyze trade under imperfect information has been extended naturally to the study of the credit market. While their models focus on different informational problems[2], they both conclude that informational asymmetries create an incentive problem, inducing banks to ration credit. Indeed, in both adverse selection and moral hazard, an increase of the interest rate on loans may adversely affect the rate of return to banks and, therefore, these may wish to hold the interest rate below the market clearing level since raising the rate would lower bank returns. Thus some borrowers will be rationed in equilibrium and will not get enough financial resources to carry out their activities.

Afterwards, a complementary stream of literature (mainly empirical) has analyzed the implication of these informational imperfections on firms' investment activities. Indeed, a prediction of these models of credit rationing is that some classes of firms (usually the youngest and the smallest) will not get the necessary resources to finance their investments. Therefore a rationed firm's demand for investment will depend positively on its balance sheet position as a strengthened balance sheet implies a borrower has more available resources to either use directly for project finance or as collateral in obtaining outside funds. This prediction has been extensively tested and the empirical findings support it generally[3].

However, the demand for capital good is not the only firm's activity which can be affected by constraints on the availability of external financial resources; indeed these can affect also the efficiency of the firm's productive

[1]For very good surveys, see Bernanke,1993, Hubbard, 1995 and Schiantarelli, 1996.

[2]Stiglitz and Weiss, first and Williamson, afterwards have examined the characteristics of the credit market equilibrium when it is affected by adverse selection and moral hazard with costly monitoring respectively.

[3]Among others, see Fazzari, Hubbard and Petersen, 1988 for an analysis of the relationship between the within-firm variation in physical investment and internal finance in a panel of U.S. manufacturing firms. Hoshy, Kashyap and Petersen, 1991 and Devereux and Schiantarelli, 1989 offer the same kind of evidence for Japanese firms and British firms, respectively.

process and its variation across time. To understand this point, consider a value-maximizing firm which is debt-constrained. As it cannot have access to additional external resources to improve its productive technology, it will try to improve technical efficiency over time to gain in productivity. Therefore, I expect that debt constrained firms usually have a better performance in terms of technical efficiency change over time than firms without finance constraints.

These considerations set the agenda for this paper. The purpose of this paper is to test whether finance constraints create an incentive for debt-constrained firms to improve efficiency along time, using a sample of firms from the Italian manufacturing over the period 1989-1994. The work is divided into two parts. I first consider the theoretical relationship between finance constraints and efficiency change. To this purpose, I derive the expression for the efficiency change for a debt constrained and value maximizing firm, and I contrast it with the equivalent one for a non-debt constrained firm. I show that tighter finance constraints create an incentive for firms to improve technical efficiency along time. Second I test empirically this prediction for a panel of Italian firms from 1989 to 1994, divided into eight sectors. The empirical analysis itself is composed into two parts: first, using a novel approach, I will derive the indices of technical efficiency change by estimating a parametric distance frontier for each sector. Then I will regress these indices on measures of finance constraints to analyze their impact on the efficiency growth of the sectors.

The structure of the paper is the following. In Section 2, I present a brief review of the theoretical literature on asymmetric information in the credit market and of the empirical literature on the impact of finance constraints on the firm's demand for investments; in Section 3, I presents the partial equilibrium model showing the impact of credit constraints on technical efficiency change. The empirical model is introduced in Section 4 while the data, the variables and the empirical results are presented and commented in Section 5. Finally some concluding remarks are offered in Section 6.

2 Credit market asymmetric information and its impact on firms' demand for investment: a brief survey

The purpose of this section is to present shortly the main results of the literature dealing with the consequences of asymmetric distribution of information on the credit market equilibrium and its subsequent effect on firm's capital accumulation. It is divided into two parts: in the first one, I will describe the theoretical literature dealing mainly with the allocative consequences of informational asymmetries in the credit market at the micro level; more specifically I will describe in some detail the seminal papers of Stiglitz and Weiss (1981) on the effects of adverse selection and of Williamson (1986) focusing on the moral hazard with costly monitoring. In the second part, I will introduce the main empirical studies examining the impact of credit constraints on firm's investment demand.

2.1 Allocative effects of informational problems in the credit market

Many of the ideas in this literature can be best understood in the context of Akerlof's (1969) paper on the "lemon" problem. This paper illustrates how asymmetric information between buyers and sellers about product quality can cause a market to malfunction. The argument runs as follows: since the market price reflects buyers' perceptions of the average quality of the product being sold, sellers of low-quality goods will receive a premium at the expense of those selling high-quality goods. This distortion in turn will affect the level of market activity; some high-quality sellers will stay out of the market and possibly enough to preclude the market from opening. The literature on financial market inefficiencies applies Akerlof's basic ideas. In a very influential paper, Stiglitz and Weiss (1981) exploit informational asymmetries to motivate a form of credit rationing where the market denies funds to borrowers with characteristics identical to those receiving loans. The authors assume that potential borrowers' projects differ in terms of riskiness unobserved to the bank. It is also assumed that banks issue standard debt that pays lenders a fixed interest rate if the project yield is sufficiently high, and pays the net yield otherwise. Thus, for a given loan rate, lenders earn a lower expected return on loans to bad-quality borrowers (those with riskier projects) than to good. This occurs because an unobserved mean-preserving spread in a borrower's project return distribution reduces the expected payment to lenders under default. Stiglitz and Weiss show that, given their assumption, the loan supply curve may bend backwards and that credit rationing can emerge as a consequence. A rise in the interest rate lowers the average borrower quality as those with relatively safe projects are the first to drop out. Thus, further increases in the interest rate may lower lender's expected return making the loan supply curve bend backwards. Rationing arises when the loan demand and supply curve do not intersect. The quantity of loans offered is the maximum the supply curve permits.

The excess demand for loans persists because adjustment in the interest rate cannot equilibrate the market; further interest rate only lower the supply of loans offered.

Other papers explore the impact of moral hazard on the credit market equilibrium. Williamson in 1986 analyses the circumstances under which moral hazard with costly monitoring can induce credit rationing. He considers the problem of a lender and borrowers interested in formulating a bilateral loan agreement. Two key premises are that the lender must pay a fixed cost to observe the returns to the borrower's project (i.e. costly state verification) and second, the borrower does not have sufficient collateral to fully secure the loan. The dilemma the lender faces is that the borrower who is unmonitored has the incentive to misreport the project outcome but that it is inefficient to commit to auditing the borrower under all circumstances. Rationing may occur because the expected default costs stemming from costly state verification may make it prohibitively expensive for borrowers to obtain funds from lenders with high opportunity costs.

Many papers[4] elaborate on these themes and the results often depend greatly on the particular informational asymmetries posed between borrowers and lenders. Two basic implications emerge from these studies: first, informational asymmetries create an incentive problem inducing banks to ration credit. Indeed, both adverse selection and moral hazard (both *ex ante* and *ex post*) may yield the result that an increase of the interest rate on loans may adversely affect the rate of return to banks; therefore banks may wish to hold the interest rate below the market clearing level since raising the rate would lower bank returns; second, these distortions can have relevant effects on firms' capital accumulation as they can reduce the efficiency of the investment process, inducing, in severe cases, an investment collapse. This latter implication has been subject to extensive empirical studies which will be described in more detail in next sub-paragraph.

2.2 Credit constraints and firm's investment demand: the empirical studies

As pointed out at the end of the previous sub-paragraph, credit rationing can have a potential remarkable impact on firm's demand for investment since they might not be able to fund their productive activities as they do not have access to sufficient external resources. If so, an immediate testable implication of these models of credit rationing is that for a debt-constrained firm, the investment demand depends positively on borrowers balance sheet

[4] Bester, 1985; Hellwig, 1986; Besanko and Thakor, 1987.

positions. Indeed a strengthened balance sheet implies it has more resources available to use directly for project finance; this reduces the borrowers' cost of obtaining external funds by lowering the informational risk that outside lenders bear and in turn stimulates investment. Such a prediction has been tested by testing the significance of cash-flow variables into models of demand for investments.

Many empirical studies, using different specifications of the investment demand and different data-sets, have showed greater failure of the perfect capital markets hypothesis for firms selected a priori to be more likely to face capital market frictions (Hubbard, 1995). The approach tests the null hypothesis of a correctly specified investment model by the significance of liquidity variables and uses their pattern across firms to suggest the alternative of finance constraints.

In their pathbreaking study, Fazzari, Hubbard and Petersen tested for the significance of liquidity effects on the demand for investment using three models of the demand for investment (i.e. the accelerator model, the Jorgenson model and the Tobin's q model[5]) using a panel of 49 firms over the period 1969-84 drawn from the Value Line data base. Firms were sorted by retention ratios under the hypothesis that firms retaining a higher percentage of their equity income must face higher costs for external funds. Therefore liquidity should be significant for high retention firms than for low retention and unconstrained firms. The main result is that, overall, investment is significantly more sensitive to current cash-flow than a frictionless neoclassical model would predict. Further, the conclusions are more dramatic for new and small firms. These finding are largely confirmed with data from different countries and different sorting of firms (Fazzari, Hubbard and Peterson, 1988; Gertler and Hubbard, 1988; Hayashi and Inoue, 1991; Hoshi, Kashyap and Scharfstein, 1992; Devereux and Schiantarelli, 1990).

[5]In this section, it is not my purpose to explain in detail the different models of the demand for investment. To this purpose, a useful survey is Schiantarelli, 1996.

Table 1: Finance constraints and demand for investments: the Tobin's q

Author	Country	Data format	Period	Source
Fazzari *et al.*	USA	Panel	1969-84	Value Line data base
Hoshi *et al.*	Giappone	Panel	1965-86	Nikkei Financial Data Tapes
Schaller	Canada	Panel	1973-86	Laval Database and Financial Post Annual Corporate Database

A second set of studies takes a similar approach but examines the finance constraints hypothesis using the Euler equation[6] supplemented with a borrowing constraint (See, among others, Gertler and Kashyap (1991), Whited, 1992; Bond and Meghir, 1994; Hubbard, Kashyap and Whited, 1995). When this constraint is binding, the associated multiplier enters the error term. This implication is evaluated by the correlation between the instruments and residuals in the over-identified model. Firms believed a priori to be constrained in financial markets tend to fail this specification tests while the remaining firms tend to pass. Further, to highlight an alternative hypothesis the multiplier is parameterized in terms of variables representing finance constraints [7].

[6]Schiantarelli, 1996.

[7]Gertler et al. (1991) have measured this variable by the spreads between the interest rates with the same maturity but different riskiness to capture the relationship between monetary policies and credit availability. Whited (1992), on the contrary, has specified the shadow cost by employing variables like the ratio between the long-run debt and the firm's values.

Table 2: Finance constraints and demand for investments: the Euler equation

Author	Country	Data Format	Period	Source
Whited	USA	Panel	1976-91	Standard and Poor's COMPUSTAT
Hubbard *et al.*	USA	Panel	1976-87	Standard and Poor's COMPUSTAT
Ng and Schaller	Canada	Panel	1973-86	Laval Database and Financial Post Annual Corporate Database

This brief survey on the empirical studies on the impact of finance constraints shows that researchers have mainly emphasized how these interfere with the accumulation of capital in the firm. However, the demand for capital good is not the only firm's activity which can be affected by constraints on the availability of external resources; indeed these can affect also the efficiency of the firm's productive process and its variation along time. To understand this point, consider value-maximizing firm which is debt-constrained. As it cannot have access to additional external resources to improve productive technology, the firm will act to improve technical efficiency over time to gain in productivity. Therefore, I expect that debt constrained firms usually have a better performance in terms of technical efficiency change over time than firms without finance constraints.

This hypothesis is formalized in the next paragraph where I derive the expression for the efficiency change for a debt constrained and value maximizing firm and I contrast it with the equivalent one for a non-debt constrained firm. I show that tighter finance constraints create an incentive for firms to improve efficiency. Afterwards, this implication is subject to an empirical test using a sample of firms from the Italian manufacturing over the period 1989-1994.

3 Technical efficiency growth and finance constraints: a partial equilibrium approach

In this paragraph, I analyze theoretically the impact of credit constraints on technical efficiency change. To this purpose, I will derive an expression for the technical efficiency change for a value maximizing firm which is not debt-constrained and I will contrast it with that for a debt-constrained firm, that is a firm which has a constraint on the amount of debt it can raise and so facing a higher shadow cost of debt. This model produces two key results: the first is that for a debt-constrained firm, technical efficiency change is affected by the shadow cost of debt, unlike the non debt-constrained firm; further, an increase in the shadow cost of debt (and a consequent tighter constraint on the available external debt) has a positive impact on firm's technical efficiency change.

Consider a representative firm with no borrowing constraints. Her objective is to maximize its value, V_0, as of period 0:

$$V_0 = \beta d_t \qquad \beta > 0 \tag{1}$$

where β_t is the discount factor at time t (or the inverse of one plus the appropriate discount rate) and d_t are the dividends at time t. The firm faces the following capital accumulation constraint:

$$k_t = (1-\delta)k_{t-1} + i_t \qquad \delta > 0 \tag{2}$$

where k_t is the capital stock at the end of period t, δ is the depreciation rate and i_t is the investment. The firm also faces a non-negativity constraint on dividends $d_t > 0$ where d_t are defined as:

$$d_t = \pi_t - w_t l_t - p_t^i i_t + b_t - (1 + r_{t-1})b_{t-1} \tag{3}$$

where π_t is the revenue function, l_t is the labour and w_t and p_t^i are the real price of labour and investment, respectively. The firm pays r_{t-1}, the after tax real interest rate on the stock of one-period debt outstanding at the end of period t_1 and issues an amount b_t of new debt each period, subject to the transversality condition of no-Ponzi game that:

$$\lim_{t\to\infty} b_t = 0 \tag{4}$$

The firm maximizes (1) subject to (2), (3) and (4). Let λ_t^k and λ_t^d be the Lagrange multipliers on capital accumulation and the non-negativity constraint on dividends, respectively. Also let H_x denote the partial derivative of the function H with respect to x. The first order conditions for capital, investment and debt are, respectively:

$$(1+\lambda_t^d)(\pi_k) + \lambda_t^k - \beta(1-\delta)\lambda_{t+1}^k = 0 \tag{5}$$

$$-\lambda_t^k = -(1+\lambda_t^d)p_t^i \tag{6}$$

$$(1+\lambda_t^d) - [(1+\lambda_{t+1}^d)\beta(1+r_t)] = 0 \tag{7}$$

From (7), I get the following expression for $(1+\lambda_t^d)$:

$$(1+\lambda_t^d) = (1+\lambda_{t+1}^d)\beta(1+r_t) \tag{8}$$

Substituting in (6), (6) gets:

$$-\lambda_t^k = -(1+\lambda_{t+1}^d)p_t^i\beta(1+r_t) \tag{9}$$

If both (8) and (9) are substituted into (5), (5) gets:

$$(1+\lambda_{t+1}^d)\beta(1+r_t)(\pi_{kt})+(1+\lambda_{t+1}^d)p_t^i\beta(1+r_t)-\beta(1-\delta)(1+\lambda_{t+1}^d)p_{t+1}^i = 0 \tag{10}$$

Divide by $\beta(1+\lambda_{t+1}^d)(1+r_t)$ and for future reference denote $\tilde{\beta}_t = \frac{\beta}{1+r_t}$. Thus the first order condition for capital gets:

$$\pi_k - p_t^i + (1-\delta)\tilde{\beta}p_{t+1}^i = 0 \tag{11}$$

The revenue function can be specified $pf(k_t, l_t)$ where p is the inverse demand function and $f(k_t, l_t)$ is the production function. I assume that the latter is homogeneous of degree $\mu = \alpha_l + \alpha_k$, that is:

$$y_t = F(k_t, l_t) = k_t^{\alpha} l_t^{1-\alpha} \qquad 0 < \alpha < 1 \tag{12}$$

with $F_i > 0$, $F_{ii} < 0$. If the firm is a price-taker, $\pi_i = pF_i = F_i$ with the price of output as the numeraire. Therefore (11) gets:

$$p\alpha k_t^{\alpha-1} l_t^{1-\alpha} - p_t^i + (1-\delta)\tilde{\beta}p_{t+1}^i = 0 \tag{13}$$

From (13), the optimal stock of capital is:

$$k_t = [\frac{p_t^i - (1-\delta)\tilde{\beta}p_{t+1}^i}{p_t\alpha l_t^{1-\alpha}}]^{\frac{1}{\alpha-1}} \tag{14}$$

while the firm's supply is given by:

$$y_t = [\frac{p_t^i - (1-\delta)\tilde{\beta}p_{t+1}^i}{p_t\alpha l_t^{1-\alpha}}]^{\frac{\alpha}{\alpha-1}} l_t^{1-\alpha} \tag{15}$$

Now, technical efficiency at time t can be defined as the ratio of output produced at time t to the total inputs used at time t, that is:

$$Eff_t = \frac{y_t}{[\frac{p_t^i - (1-\delta)\tilde{\beta}p_{t+1}^i}{p_t\alpha l_t^{1-\alpha}}]^{\frac{\alpha}{\alpha-1}} l_t^{1-\alpha}} \tag{16}$$

Efficiency change can then be defined as the change in technical efficiency between t and $t+1$, that is:

$$\frac{Eff_{t+1}}{Eff_t} = \frac{y_t}{y_{t+1}} \frac{[\frac{p^i_{t+1}-(1-\delta)\tilde{\beta}p^i_{t+1}}{p_{t+1}\alpha l_t^{1-\alpha}}]^{\frac{\alpha}{\alpha-1}} l_t^{1-\alpha}}{[\frac{p^i_t-(1-\delta)\tilde{\beta}p^i_{t+1}}{p_t\alpha l_t^{1-\alpha}}]^{\frac{\alpha}{\alpha-1}} l_t^{1-\alpha}} \tag{17}$$

Now, the efficiency change can also be written as the ratio between two distance functions, defined in two successive time periods. Therefore (17) gets:

$$\frac{Eff(t+1)}{Eff(t)} = \frac{y_t}{y_{t+1}} \frac{[\frac{p^i_{t+1}-(1-\delta)\tilde{\beta}p^i_{t+1}}{p_{t+1}\alpha l_t^{1-\alpha}}]^{\frac{\alpha}{\alpha-1}} l_t^{1-\alpha}}{[\frac{p^i_t-(1-\delta)\tilde{\beta}p^i_{t+1}}{p_t\alpha l_t^{1-\alpha}}]^{\frac{\alpha}{\alpha-1}} l_t^{1-\alpha}} = \frac{D_o^{t+1}(x^{t+1}, y^{t+1})}{D^t(x^t, y^t)} \tag{18}$$

From (18), it can be clearly seen that efficiency change does not depend on financial variables for a non-debt constrained firm; indeed it depends only from the physical qualities of inputs and output used by the firm in the production process. Consider, now, a debt constrained firm. The feature of asymmetric information can be modelled as a debt capacity constraint on the firm. If b_t is the maximum amount of debt that the firm is allowed to issue and b_t^* is the optimal amount of debt, then the firm is subject to an additional constraint, that is:

$$b_t \leq b_t^* \tag{19}$$

Now the firm's problem gets to maximize (1) subject to (2), (3) and the new constraint on debt (19). Let ω_t be the Lagrange multiplier on the debt constraint. The first order condition for b_t now becomes:

$$(1+\lambda_t^d) - [\beta(1+\lambda_{t+1}^d)(1+r_t)] - \omega_t = 0 \tag{20}$$

This can be rewritten as:

$$(1+\lambda_t^d) = \beta(1+\lambda_{t+1}^d)(1+r_t) + \omega_t \tag{21}$$

Substituting in (6), I get:

$$-\lambda_t^k = -[(1+\lambda_{t+1}^d)\beta(1+r_t) + \omega_t]p_t^i \tag{22}$$

Substituting (22) and (21) into (5), I get the new first order condition for capital:

$$\pi_k(\beta)(1+\lambda^d_{t+1})(1+r_t)+\omega_t)+(\beta(1+\lambda^d_{t+1})(1+r_t)+\omega_t)p^i_t-\beta(1-\delta)(1+\lambda^d_{t+1})p^i_{t+1}=0 \tag{23}$$

Dividing (23) by $\beta(1+\lambda^d_{t+1})(1+r_t)$, I get:

$$\pi_k(1+\frac{\omega_t}{\beta(1+\lambda^d_{t+1}(1+r_t)})+(1+\frac{\omega_t}{\beta(1+\lambda^d_t)(1+r_t)})p^i_t-\frac{(1-\delta)p^i_{t+1}}{(1+r_t)}=0 \tag{24}$$

Define $\tilde{\omega}=\frac{\omega}{(1+\lambda^d_t)}$. (24) gets:

$$\pi_k+\pi_k\tilde{\omega}_t+p^i_t+\omega_t p^i_t-\tilde{\beta}(1-\delta)p^i_{t+1}=0 \tag{25}$$

or rearranging:

$$(1+\tilde{\omega}_t)\pi_k+p^i_t(1+\tilde{\omega}_t)-\tilde{\beta}(1-\delta)p^i_{t+1}=0 \tag{26}$$

Divide (26) by $(1+\tilde{\omega})$:

$$\pi_k+p^i_t-\tilde{\beta}(1+\tilde{\omega})^{-1}(1-\delta)p^i_{t+1}=0 \tag{27}$$

Recalling (12), (27) gets:

$$p_t\alpha k_t^{\alpha-1}l_t^{1-\alpha}-p^i_t-\tilde{\beta}(1-\tilde{\omega})^{-1}(1-\delta)p^i_{t+1}=0 \tag{28}$$

The demand for capital is:

$$k_t=(\frac{p^i_t+\tilde{\beta}(1-\tilde{\omega}_t)^{-1}(1-\delta)p^i_{t+1}}{p_t\alpha l_t^{1-\alpha}})^{\frac{1}{\alpha-1}} \tag{29}$$

where $\frac{\partial k_t}{\partial\tilde{\omega}_t}=-\frac{1}{(p_t\alpha l_t^{1-\alpha})^{\frac{1}{\alpha-1}}}\frac{1}{\alpha-1}(p^i_t+\tilde{\beta}(1-\tilde{\omega}_t)^{-1}(1-\delta)p^i_{t+1})^{\frac{2+\alpha}{\alpha-1}}\tilde{\beta}(1-\tilde{\omega})^{-2}(1-\delta)p^i_{t+1}<0$.

The firm's supply is given by:

$$y_t=(\frac{p^i_t+\tilde{\beta}(1-\tilde{\omega}_t)^{-1}(1-\delta)p^i_{t+1}}{p_t\alpha l_t^{1-\alpha}})^{\frac{\alpha}{\alpha-1}}l_t^{(1-\alpha)} \tag{30}$$

Now technical efficiency at time t can be defined as the ratio of output produced at time t to the total inputs used at time t, that is:

$$Eff_t=\frac{y_t}{(\frac{p^i_t+\tilde{\beta}(1-\tilde{\omega}_t)^{-1}(1-\delta)p^i_{t+1}}{p_t\alpha l_t^{1-\alpha}})^{\frac{\alpha}{\alpha-1}}l_t^{(1-\alpha)}} \tag{31}$$

Efficiency change can then be defined as the change in technical efficiency between t and $t+1$, that is:

$$\frac{Eff_{t+1}}{Eff_t} = \frac{y_t}{y_{t+1}} \frac{(\frac{p^i_{t+1}+\tilde{\beta}(1-\tilde{\omega}_{t+1})^{-1}(1-\delta)p^i_{t+1}}{p_{t+1}\alpha l^{1-\alpha}_{t+1}})^{\frac{\alpha}{\alpha-1}} l^{(1-\alpha)}_{t+1}}{(\frac{p^i_t+\tilde{\beta}(1-\tilde{\omega}_t)^{-1}(1-\delta)p^i_{t+1}}{p_t\alpha l^{1-\alpha}_t})^{\frac{\alpha}{\alpha-1}} l^{(1-\alpha)}_t} \tag{32}$$

where

$$\frac{\partial f(.)}{\partial \tilde{\omega}_t} = \frac{y_t}{y_{t+1}} (\frac{p^i_{t+1} + \tilde{\beta}(1-\tilde{\omega}_{t+1})^{-1}(1-\delta)p^i_{t+1}}{p_{t+1}\alpha l^{1-\alpha}_{t+1}})^{\frac{\alpha}{\alpha-1}} \tag{33}$$

$l^{(1-\alpha)}_{t+1}(\frac{p_t\alpha l^{1-\alpha}_t}{p^i_t+\tilde{\beta}(1-\delta)p^i_{t+1}})^{\frac{\alpha}{\alpha-1}} l^{1-\alpha}_t \frac{\alpha}{\alpha-1}(1-\omega_t)^{\frac{1}{\alpha-1}} > 0$

Unlike the equivalent expression for non debt constrained firms, now the technical efficiency change is a function of the shadow cost of debt, that is it is affected by costs firms bear to get additional external resources. From (33), an increase in the shadow cost of debt results into an increase into technical efficiency change; indeed, the less resources are available to improve the productive technology, the more incentive the firm has to improve the efficiency of the productive process to get productivity gains.

This prediction has been tested using a panel of Italian firms from 1989 to 1994, divided into eight sectors. The empirical analysis is divided into two parts: first, I will derive the technical efficiency indices by using a novel approach based on the estimation of a stochastic parametric distance function. Then I will regress these indices on measures of finance constraints to analyse their impact on the technical efficiency growth for each sector. The empirical approach is explained in more detail in the next section.

4 Technical efficiency change and stochastic parametric distance functions: the empirical framework

In the previous paragraph, a theoretical model has been presented from which the expression of technical efficiency change for a value-maximizing and debt-constrained firm has been derived, first, and then compared with the equivalent one for a non debt constrained firm. For debt-constrained firms, technical efficiency change is affected by the shadow cost of debt, unlike the firm without credit constraints; furthermore it has been shown that, as the shadow cost of debt increases, the efficiency change varies positively.

The main empirical prediction from this model is that the change of technical efficiency is affected positively by variations in the shadow cost of debt for firms supposed to be credit-constrained. This prediction is tested in the second part of this paper. In this paragraph, I will detail the empirical approach used. It is composed of two parts: first, using a novel approach based on the estimation of parametric stochastic distance functions, I will derive indices of technical efficiency change by estimating a parametric stochastic distance function for each sector. Then, I will regress these indices on measures of finance constraints to analyze their impact on the efficiency growth within each sector. In the next sub-section, I will show how to estimate a distance function using stochastic methods and how to get measures of technical efficiency change from the estimates. Next, I will give an overview of the procedure followed in the second stage estimation.

4.1 An empirical model for the estimation of a stochastic, parametric distance functions

The purpose of this subsection is to show how to derive measures of efficiency change estimating a parametric stochastic distance function. A production technology may be represented in many ways. The majority of researchers in this area is familiar with the use of production, cost and profit functions as alternative methods of describing a production technology. It was not until recent years that applications involving distance functions have begun to appear in number (Fare et al., 1993; Lovell *et al.*, 1994 and Grosskopf *et al.*, 1996). However, so far distance functions have been computed using non-parametric methods. Recently, some applications using parametric methods have started to appear (Coelli and Perelman, 1996). Estimating stochastic parametric distance functions has some advantages with respect to non-parametric methods: first, it lets to test hypothesis like the presence of returns to scale while allowing an appropriate treatment of measurement of errors and random shocks in production; second, it is characterized by the absence of slacks either in inputs or outputs, unlike non-parametric methods.

To estimate a parametric distance function, I have first to choose a functional form for the transformation function $P^t(x_{it})$ that must be ideally flexible, be easy to derive and permits the imposition of homogeneity (Coelli and Perelman, 1996). The translog function has these properties and it is the preferred functional form starting from the seminal papers by Lovell et al. (1994) and Grosskopf et al. (1997). The output distance function is defined here in a logarithmic form for a panel of I producers observed over T periods. The specification I adopt for the transformation function for firms operating in the manufacturing sector corresponds to a one-output, multi-input technology with technical progress:

$$lnD_o^t(x^{it},y^{it}) = \alpha_o + \Sigma_{k=1}^K \alpha_k lnx_k^{it} + 0.5\Sigma_{k=1}^K \Sigma_{l=1}^L \alpha_{kl} lnx_k^{it} lnx_l^{it} + \tag{34}$$

$$\Sigma_{l=1}^L \alpha_l lnx_l^{it} + \Sigma_{l=1}^L \delta_l lnx_l^{it} lny^{it} + \Sigma_{k=1}^K \delta_k lnx_k^{it} lny^{it} + \beta lny^{it} +$$
$$+\gamma t + 0.5\gamma t^2 + \Sigma_{k=1}^K \mu_k lnx_k^{it} t + \mu lny^{it} t \qquad i = 1, ..., I \qquad t = 1, ..., T$$

where k and l are the capital and labour respectively, i denote the firms and t the time. The isoquant of the output set corresponds to $lnD_o^t(x^{it},y^{it}) = 0$ and interior points to $-\infty < lnD_o^t \leq 0$. The parameters of the function must satisfy some restrictions like the usual restrictions for symmetry and homogeneity of degree 1 on outputs; this implies:

$$\beta = 1 \tag{35}$$

The time trend appears in three different way: in a second order polynomial in t whose effect is that of controlling for neutral technical change; associated with inputs to test for potential technical change embodied in specific inputs; in association with the output as a way to test for the presence of technical change bias in the output bias.

To apply econometric frontier approaches, the function must be transformed into a manageable form. Lovell et al. (1994) observed that homogeneity on outputs implies:

$$D_o^t(x^{it}, \omega y^{it}) = \omega D_o^t(x^{it}, y^{it}) \qquad \omega > 0 \tag{36}$$

I can choose the output y^{it} and set $\omega^{it} = \frac{1}{y^{it}}$. I can rewrite (34) as follows[8]:

$$ln[D_o^t(x^{it},y^{it})/y^{it}] = \alpha_o + \Sigma_{k=1}^K \alpha_k lnx_k^{it} + 0.5\Sigma_{k=1}^K \Sigma_{l=1}^L \alpha_{kl} lnx_k^{it} lnx_l^{it} \tag{37}$$

$$\Sigma_{l=1}^L \alpha_l lnx_l^{it} + \Sigma_{l=1}^L \delta_l lnx_l^{it} lny^{it} + \Sigma_{k=1}^K \delta_k lnx_k^{it} lny^{it} + \beta ln(y^{it}/y^{it}) +$$
$$\gamma t + 0.5\gamma t^2 + \Sigma_{k=1}^K \mu_k lnx_k^{it} t + \mu_m ln(y^{it}/y^{it}) t \qquad i = 1, ..., I \qquad t = 1, ..., T$$

or:

$$lnD_o^t(x^{it},y^{it}) - lny^{it} = TL(x^{it}, t; \alpha, \beta, \delta, \gamma, \mu, \epsilon) \tag{38}$$

[8] See Perelman and Coelli (1996) for more information.

and hence:

$$-lny^{it} = TL(x^{it}, t; \alpha, \beta, \delta, \gamma, \mu, \epsilon) - lnD_o^t(x^{it}, y^{it}) \tag{39}$$

Setting $-lnD_o^t(x^{it}, y^{it}) = u^{it}$ and adding a stochastic term, we find the familiar representation of a parametric stochastic frontier:

$$-lny^{it} = TL(x^{it}, t; \alpha, \beta, \delta, \gamma, \mu, \epsilon) + \epsilon^{it} \tag{40}$$

where $\epsilon^{it} = u^{it} + v^{it}$, that is the composed error term allowing for inefficiency in production and noise. The predicted value of the output distance function for producer i in period t can then be estimated as a conditional expectation:

$$D_o^i(x^{it}, y^{it}/y_M^{it}) = E(exp(-u^{it})|\epsilon^{it}] = \frac{1 - \Phi(\sigma_A - \epsilon^{it}/\sigma_A)}{1 - \Phi(\chi\epsilon^{it}/\sigma_A} exp(\epsilon^{it} + \sigma_A^2/2) \tag{41}$$

where $\sigma_A = \sqrt{(1 - \sigma^2)}$, $\sigma^2 = \sigma_u^2 + \sigma_v^2$ and $\Phi(.)$ represents the distribution function of a standard normal random variable[9].

Efficiency change is computed as the ratio of two successive distance functions. Dealing with stochastic frontiers, distance functions are represented by estimated conditional expectations. Therefore efficiency change is defined as follows:

$$\Delta TE = \frac{exp(-\hat{u}^t)}{exp(-\hat{u}^{t+1})} \tag{42}$$

Technical change at the frontier level can be estimated as the time derivates of the distance function:

$$\frac{\partial TL(.)}{\partial t} = \hat{\gamma} + \hat{\gamma}_t t + \Sigma_k^K \hat{\epsilon}_k ln x_k^{t+1} + \Sigma_m^{M-1} \hat{\mu}_m ln(y^{t+1}/y^{t+1}) \tag{43}$$

with $\frac{\partial TL(.)}{\partial t} < 0$ for positive technical change and $\frac{\partial TL(.)}{\partial t} > 0$ for technical regress.

4.2 Technical efficiency change and finance constraints: the second stage estimation

In this subsection, I will explain briefly the empirical approach used to assess the impact of finance constraints on technical efficiency change. To this

[9] Note that conditional expectation is a modification of Jondrow et al. (1992) and Battese and Coelli (1988).

purpose, I regress the technical efficiency change indices derived as explained in the previous sub-section on measures of the shadow cost of capital, after controlling for eventual variables affecting the change in technical efficiency[10].

The choice of measures of finance constraints for the second stage estimation is a delicate matter. However, the empirical literature on the relationship between finance constraints and debt constrained firm's demand for investment offers useful suggestions. Two specifications have been considered in this literature. The first uses the risky spread (defined as the difference between a risky interest rate and a riskless interest rate on securities of the same maturity) as a proxy of agency costs firms incur. The idea that the spread might capture agency costs of financial intermediation has been suggested by Bernanke and Gertler (1980). They used it to parameterize the shadow cost of finance constraints in the Euler equation for the asymmetric information model and found a statistically significant relationship between the risky spread and aggregate investment in the U.S. Therefore, it can be thought of as capturing the effect of aggregate shocks to internal net worth which might affect the shadow cost of finance. The second specification uses the debt-to equity ratio and interest coverage ratios as firm-specific measures of agency costs (Whited, 1992 and Ng and Schaller, 1996). In this work, I will use the second specification of the shadow cost of capital. More specifically, I use the debt to asset ratio, which is measured by the ratio of the market value of the firm's debt to the market value of its total assets, and the coverage interest ratio, which given by the ratio between the interest expenses and the cash-flow. The former variable is a measure of the firm's current demand for borrowing relative to its debt capacity, usually proxied by the market value of the firm. Of course, the range of the variable is between 0 and 1: a value close to 0 implies a low level of indebtedness while a value close to 1 shows a high level of indebtedness and therefore, the probability of getting new debt is low. The latter proxy for the shadow cost of capital indicates the likelihood of firm's financial distress relative to its fundamental health or need to borrow. It captures the idea that if a firm can generate sufficient internal funds, it will not have a great need to borrow and will not be likely to run up its debt limit. Again the range of this variable is between 0 and 1: a value close to 0 is a sign of good health of the firm, while a value close to 1 indicates a high probability of default for the firm; in this case, a firm is likely to be debt-constrained.

In this second stage, I control for the impact of firm's capital accumulation on the variation of technical efficiency over time. Indeed, it is reasonable to assume that the firm's adoption of new technologies and of new capital

[10]In this respect, I follow Hay and Liu, 1997.

can contribute to improve its productive process and therefore its technical efficiency over time. Therefore, not controlling for this effect may bias the estimates. To this purpose, I follow the suggestion by Scott (1991) that the appropriate contribution of capital accumulation to a firm's improvement in the productive process should be measured by gross investment. Indeed gross investment incorporates new techniques and therefore does more for output than merely replacing old capital. Old capital stock may be scrapped not because it is "worn out" in some sense but because it is technically obsolete. Therefore, to this purpose, I introduce the investment ratio (and its square) as regressors in the second stage estimation, where investment ratio is defined as the ratio between gross investment and capital stock.

The empirical specification of this equation, however, raises some problems. First, in the equation to estimate, the dependent variable is specified as Δu. Note that Δu is implicitly a first difference of log values: it is therefore appropriate to express all regressors as first differences in logs. Second, it is appropriate to account for firms' heterogeneity in running the estimates. Indeed, firms are heterogeneous in both their adjustment to the business cycle shocks and their firm-specific characteristics. Therefore, I will use three different estimators to estimate this equation. The first is the Ordinary Least Squares (OLS). Usually, OLS estimator does not allow for firm's heterogeneity. Of course, this assumption is hard to maintain as it implies that firms are the same in both reacting to the business cycle and in their productive processes. However, OLS estimates provide a useful benchmark and therefore I decided to run them.

To relax the assumption required by OLS, I can assume that all firms face a common business cycle and adjust capacity utilization in response to business cycle in a similar manner. This amounts to define the constant of the model as the sum of a time trend capturing the response in terms of capacity utilization to the business cycle impact and a firm-specific constant capturing the effect of firm-specific characteristics, like managerial ability and input quality. These factors are usually observable to the manager of the firm but not observable to the econometrician. There are no reasons why these omitted factors should take the same value for all firms. However, these can have characteristics that make them vary across firms but remain constant over time. To estimate the equations under this latter assumption, the estimators from the panel data literature are of help. The estimates of the parameters will depend crucially upon whether I assume the constant to be fixed effect or random effect. In the first case, the best linear unbiased estimator (BLUE) is OLS applied on the differences from the time average; the estimator is also called the *Within estimator*. The random effect model, on the contrary, assumes that the firm-specific factors which affect the efficiency change, but not included explicitly as regressors, can have the characteristics of a random variable similar in nature to the Normal Law of Errors. In this case the BLUE estimator is the Generalized Least Squares (GLS) estimator. To choose between these models, a useful statistics is the Hausmann test (1978). It is based on the idea that under the hypothesis of no correlation, both OLS in the Fixed Effect model and GLS are consistent but OLS is inefficient, while under the alternative OLS is consistent but GLS is not. Therefore, under the null hypothesis, the two estimates should not differ systematically, and a test can be based on the difference.

Finally, this empirical specification may be affected by two econometric problems: first, it is necessary to be sure that the correct causality is identified between finance constraints and technical efficiency indices. Indeed in this empirical specification, I assume that variations of the shadow cost of capital improve firm's technical efficiency over time and not viceversa. Therefore, it is important to test for the exogeneity of the measures of finance constraints. Second, I need to run some additional tests to detect eventual correlation between the error term and the regressors. Autocorrelation may arise from not specifying dynamic relationships within the general specification. Such a correlation may render biased and inconsistent the parameter estimates and make invalid the standard distributions to conduct significance tests of parameter estimates.

For these reasons, I conduct the Wu-test to test for both the absence of correlation between regressors and the error term and the exogeneity of finance constraints measures. Wu (1973, 1974) proposed a series of tests in cases where instrumental variables exist for regressors which are correlated with the error term. His statistics T_2 has been shown (Nakamura and Nakamura, 1981) to be asymptotically equivalent to the simpler F-test suggested by Hausman (1978). The approach suggested is therefore the following: the first step is to obtain the predicted values of the set of right-hand side variables which are presumably correlated with the error term by regressing them on a set of instrumental variables that includes regressors which are uncorrelated with the errors. The next step is to run a regression of the original regression equation augmenting the right-hand variables with these predicted values of the regressors. The Wu-test is equivalent to conducting the F-test of the null hypothesis that the regression coefficients of the predicted values are zero.

5 Empirical results

5.1 The data and the variables

The empirical analysis has been conducted on a panel of 1124 firms drawn from the Mediocredito Centrale database, observed over the period 1989-1994. These firms have been then divided into the eight main sectors of the Italian manufacturing, that is the Extraction of Metals, Transformation of Metals, Food, Tobacco, Textiles, Leather, Wood and Paper. Next, I have derived the measures of inputs and output of these firms. Following previous studies on the efficiency and productivity of the manufacturing sector (Siegel, 1995), I have measured output by the monetary added value. However, this figure has been deflated properly; the employed deflators have been derived by dividing the added value at constant prices by the added value at constant prices (at prices 1990, namely). These two figures have been taken from the Italian National Contability, prepared by Golinelli and Monterastrelli (1990).

The capital has been measured by the gross fixed capital stock. As this measure is available at market prices, it has been deflated by the deflator of the gross fixed investment for each sector provided by ISTAT (Italian Central Institute for Statistics). This latter has been computed by dividing the gross fixed investment at current prices with the gross fixed investment at constant prices. The labour input has been measured by average number of employees per firm[11].

Table 3 presents the average value of the deflated monetary added value, deflated gross fixed capital and number of employees divided by sectors and years.

[11] Data from the balance sheets do not allow to distinguish among categories of workers.

Sector	Year	Added value	Fixed Assets	Employees	Sector	Year	Added value	Fixed Assets	Employees
Extr. Met.	1989	8733	16413	113	Textiles	1989	22716	33552	237
	1990	7725	15224	106		1990	11860	18232	160
	1991	9368	21287	115		1991	20055	35441	226
	1992	10527	27568	130		1992	12550	19287	152
	1993	10192	23925	119		1993	20628	35978	212
	1994	10016	17488	106		1994	18223	30518	185
Tr. Met.	1989	12618	15853	176	Leather	1989	42476	73507	696
	1990	7973	12063	129		1990	12384	37471	211
	1991	13109	18798	182		1991	3972	8719	120
	1992	12614	15032	278		1992	10171	18364	193
	1993	9307	12835	147		1993	8886	17839	186
	1994	12750	15117	183		1994	14014	37739	232
Food	1989	9464	11377	151	Wood	1989	8013	6055	202
	1990	10430	14287	162		1990	7127	5914	149
	1991	9563	14445	135		1991	8057	8004	162
	1992	13276	13298	176		1992	7535	7181	156
	1993	19512	21967	270		1993	6644	6107	134
	1994	19910	16682	273		1994	6450	5349	120
Tobacco	1989	16269	30895	207	Paper	1989	5735	7877	111
	1990	10219	17817	138		1990	5669	8337	105
	1991	21219	40664	186		1991	6858	11591	113
	1992	14275	27802	152		1992	7184	12946	113
	1993	14400	30688	156		1993	6550	9745	104
	1994	18441	43612	189		1994	6772	9574	112

Table 3: Average added value, average gross fixed capital and average number of employees divided by year and sector

A brief look at the data contained in this table shows that all the sectors have shared the same cyclical evolution as the whole economy. In the Extraction of Metals, added value has decreased in 1990; however, it increased again in 1991 and 1992. The growth stops in 1993 and in 1994 when, in spite of the general relaunch of the economy, the decline in output continued. This may be due to the lack of exposure to foreign markets and therefore the sector has not benefited from the export-led growth. The same evolution from year to year is shared by fixed assets and by employment. Fixed assets declines in 1990 to increase in 1991 and 1992. However, the accumulation of capital stops in 1993 and 1994 definitely. Equally, the growth of employment halts in 1990 while it starts again in 1991 and 1992, to stop again in 1993 and 1994. In the Transformation of Metals, the same pattern as for the previous sector is followed by the added value, fixed assets and employment. In 1990, these variables do not increase. The growth starts again in 1991 and 1992, while they stop again in 1993. In 1994, the sector has started to grow again with a remarkable jump in production, following an analogous boost in fixed assets and employees. As for the Food sector, added value, along with fixed assets and employees, slows down. However, the sector hits the minimum level of production in 1992, before the rest of the economy. Furthermore, it start to grow again in 1992. In 1993 and 1994, clearly the sectors faces an expansionary period. In the Tobacco sector, the growth of production, fixed assets and employment stops in 1990 and 1992. In 1993, these values increase again, but they slow in 1994. Textiles begin a big disinvesting process in 1990, while production is more than halved together with employment. The process continues in 1991 where production and employment reach the lowest level. The disinvesting process is inverted in 1992 where fixed assets increase even if they do not reach the same levels as in 1990. In 1993, the general recession hits the sector as well and therefore production decreases again even if the level of employment is more or less constant. In 1994, both employment and capital increase, in correspondence with added value. In the Leather sector, added value decreases slightly in 1990; afterwards, it increases in 1991. Again there is a slump in 1992, which is followed by a continuos decrease from 1992 to 1994. The sector is also characterized by a continuous decrease in employment, jointly with a disinvesting process. The Wood sector has a continuous growth from 1989 to 1992, coupled with a strong accumulation. After 1993, however, production decreases notably along with the held fixed assets. Notice, however that throughout the period, the employment has been more or less constant.

Table 3 shows the average value of the Debt to Asset ratio (DAR henceforth) and of Interest Coverage Ratio (ICR, from now on) for each sector and for each year.

Variable	Sector	1989	1990	1991	1992	1993	1994
DAR	Extr. Met	0.244567	0.231102	0.162587	0.148825	0.197445	0.177236
	Tr. Met.	0.13456	0.144576	0.166047	0.185386	0.181739	0.215029
	Food	0.18768	0.195161	0.211648	0.201381	0.204036	0.180864
	Tobacco	0.13567	0.154365	0.15893	0.190042	0.168051	0.104423
	Textiles	0.13896	0.138784	0.141875	0.129372	0.151704	0.11645
	Leather	0.13569	0.134416	0.147011	0.129951	0.157379	0.11618
	Wood	0.15679	0.169333	0.221098	0.22105	0.235448	0.22014
	Paper	0.23564	0.239648	0.22791	0.193107	0.195135	0.152643
ICR	Extr. Met	0.54674	0.54678	0.55678	0.56879	0.56479	0.57879
	Tr. Met.	0.59789	0.595114	0.561802	0.592066	0.641751	0.645156
	Food	0.58968	0.595161	0.611648	0.601381	0.604036	0.580864
	Tobacco	0.55678	0.554365	0.55893	0.590042	0.568051	0.504423
	Textiles	0.57869	0.588145	0.602362	0.635997	0.663198	0.642574
	Leather	0.52970	0.536329	0.543767	0.576809	0.593712	0.571138
	Wood	0.61235	0.614947	0.598818	0.644008	0.666651	0.63928
	Paper	0.46879	0.48153	0.527404	0.524301	0.591439	0.589461

Table 4: The average debt to asset ratio and interest coverage ratio, divided by year and sector

Note: DAR is the Debt-to asset ratio, while ICR is the interest coverage ratio.

From the data contained in the table, it clearly emerges that the sectors are homogenous in terms of DAR: this means that firms generally decide to finance only a fixed share of their physical investment by debt as this proportion is regarded safe for the financial health of the firm. For the sector of Extraction of metals, the DAR has decreased along time, with the only exception of 1993. The opposite trend can be found for the sector of Transformation of Metal, whose DAR has increased over time. In the Food industry, it continuously increased until 1991, while decreasing afterwards. In the Tobacco industry, the DAR increased until 1992, while decreased afterwards. More complicated is the behaviour of the DAR for the Textiles sector: indeed, it increased until 1991 and then decreased in 1992; however, it started increasing again in 1993 to fall down again in 1994. The Leather Sector shared the same pattern. For the Wood sector, the DAR increased over time, while for firms in the Paper sector, DAR decreases continuously over time.

As for the ICR there is no clear difference among sectors. In general all have a ratio around 0.50 which implies that the interest expenses are very high given the firm's cash-flow. For the sector of Extraction of metals, the ICR is generally constant across years. For the Transformation of metals, the ICR is (more or less) the same until 1992 to increase in 1993 and 1994. For the Food processing sector, the ICR grows from 1989 to 1991, while decreasing slightly afterwards. In the Tobacco industry, the ICR is more or less constant until 1992, however, in 1993 it starts decreasing fast. For Textiles, it increases steadily until 1993 to decrease suddenly in 1994. The same pattern is shared by the Leather sector, where it increases until 1993 and then decreases in 1994. It increases until 1993 to decrease in 1994 in the Leather sector. In the Wood sector, the ICR has a more volatile pattern: it is constant until 1991 and then it increases again in 1992 and 1993. However in 1994, it goes down again. Finally in the Paper sector, the ICR increases constantly from 1989 till 1993, while it decreases in 1994 slightly.

5.2 The estimation of the parametric stochastic distance function: the empirical results

Table 5 presents the Maximum Likelihood Estimates of the distance Functions. The main results can be summarized as follows. First order coefficients have the expected signs on the behalf of economic behaviour. However, notice that for Transformation of Metals, parameters associated with labour and capital are not significant, while for the Wood sector the parameter associated with labour is not significant. Technical change is generally significant; however, for the Extraction of Metals and Transformation of Metals the time trend is not significant thus suggesting that embodied and squared technical change are more important in this sector. For Food sector, the squared time trend is not significant together with the labour embodied time trend. For sectors of Tobacco, Leather and Paper, they're no significant technical change, while for the sector of Textiles the squared time trend is not significant. For the Sector of Wood only embodied technical change is significant.

As for the returns of scale, there is a mixed evidence[12]. For the sectors of Extraction of metals, Transformation of Metals and Paper, firms operate under decreasing returns to scale; indeed, the sum of the coefficients of labour and capital is less than 1 for these sectors. The remaining sectors operate under constant returns to scale as the sum of coefficients is around 1.

The Table also shows the total residual variance (σ^2) and the variance of

[12] As usual for translog function approximations, the estimations were performed with lnx_I and lny expressed in deviations with respect to average values.

the inefficiency term weighted upon the total residual variance (γ). These values allow to get the variance of the inefficiency term, σ_u^2. This figure is generally low for all sector with the only exception of the Tobacco sector.

Sector	Variables	Parameters	t-ratio	Sector	Variables	Parameters	t-ratio
Ex. Met.	Constant	-4.62	-6.47	Tex.	Constant	-2.74	-3.09
	L	-0.16	-0.18		L	-0.24	-2.31
	K	-0.14	-0.78		K	-0.73	-3.82
	$K * L$	0.007	0.09		$K * L$	-0.090	-0.78
	T	-0.005	1.48		T	-0.002	-0.40
	T^2	-0.03	-2.23		T^2	-0.004	-0.28
	$L * T$	-0.04	-2.83		$L * T$	0.001	0.08
	$K * T$	0.02	2.12		$K * T$	0.008	0.57
	γ	0.27			γ	0.20	
	σ^2	0.17			σ^2	0.23	
	σ_u^2	0.046			σ_u^2	0.046	
	N. Obs.	324			N. Obs.	270	
Tr. Met.	Constant	-3.20	-13.4	Leat.	Constant	- 3.15	-12.2
	L	-0.25	-8.05		L	-0.28	-1.83
	K	-0.52	9.47		K	-0.56	-7.68
	$K * L$	-0.05	-1.63		$K * L$	-0.011	-0.26
	T	-0.002	-0.15		T	-0.004	-2.40
	T^2	-0.016	-3.39		T^2	-0.005	-1.02
	$L * T$	-0.02	-2.89		$L * T$	-0.019	-2.17
	$K * T$	0.01	3.00		$K * T$	0.014	2.46
	γ	0.002			γ	0.014	
	σ^2	0.15			σ^2	0.15	
	σ_u^2	0.0003			σ_u^2	0.0021	
	N. Obs.	1662			N. Obs.	1410	

Sector	Variables	Parameters	t-ratio	Sector	Variables	Parameters	t-ratio
Food	Constant	- 1.51	2.13	Wood	Constant	-2.50	-12.4
	L	-0.36	-1.43		L	-0.31	-9.27
	K	-0.75	-5.73		K	-0.66	-4.83
	$K*L$	-0.36	-3.68		$K*L$	-0.11	-0.89
	T	0.01	2.45		T	0.0004	0.025
	T^2	0.004	0.37		T^2	-0.002	-0.16
	$L*T$	-0.004	-0.29		$L*T$	-0.0007	-0.11
	$K*T$	0.01	1.39		$K*T$	0.007	1.74
	γ	0.007			γ	0.020	
	σ^2	0.16			σ^2	0.21	
	σ_u^2	0.0011			σ_u^2	0.0042	
	N. Obs.	258			N. Obs.	1368	
Tobacco	Constant	-3.11	-8.97	Paper	Constant	-3.72	-4.99
	L	-0.18	-3.78		L	-0.09	-1.06
	K	-0.68	-7.72		K	-0.58	-3.20
	$K*L$	-0.07	-1.67		$K*L$	0.06	0.63
	T	0.003	1.34		T	-0.001	-0.29
	T^2	-0.01	-1.58		T^2	-0.031	-1.93
	$L*T$	-0.02	-2.53		$L*T$	-0.017	-0.84
	$K*T$	0.01	2.88		$K*T$	-0.004	0.34
	γ	0.65			γ	0.09	
	σ^2	0.36			σ^2	0.22	
	σ_u^2	0.234			σ_u^2	0.019	
	N. Obs.	486			N. Obs.	720	

Table 5: Maximum Likelihood parameters of the stochastic distance functions for each sector

Note: L,K, T are the labour, capital and time trend respectively. σ^2 is the total residual variance, while γ is the variance of the inefficiency terms weighted upon the total variance. The number of observations is obtained after removing missing values and outliers.

Table 6 presents the mean value per year of technical efficiency and technical efficiency change. In general, sectors of the Extraction of Metals, of Transformation of Metals, of Food and of Leather have a positive technical efficiency growth, while the remaining ones have a continuous fall in efficiency over years. For firms within the Extraction of Metals, the mean efficiency level is low at the beginning but it increases very fast; Transformation of

Metals has a very high value of mean efficiency which is more or less constant over time. The Food industry has a low mean value of efficiency change, but it has a fast increase in efficiency; the Tobacco industry has a very low level in efficiency but registers a deep decrease in efficiency over time. The opposite is true for the Textiles where the mean level of efficiency is high whereas the decrease in technical is pretty slow. The Leather sector has a low level of efficiency but this increases over time. The Wood sector has first a slight decrease while it decreases very steeply. The Paper sector has a low level of efficiency decreasing over time.

Sector	Year	Mean Technical Efficiency	Mean Efficiency change
Extr. Met.	1989	0.75	-
	1990	0.80	0.93
	1991	0.84	1.13
	1992	0.87	0.96
	1993	0.90	0.96
	1994	0.92	1.06
Transf. Met.	1989	0.994	-
	1990	0.994	1
	1991	0.995	0.998
	1992	0.993	1.00
	1993	0.994	0.998
	1994	0.994	1
Food	1989	0.74	-
	1990	0.85	0.87
	1991	0.91	0.93
	1992	0.95	0.95
	1993	0.97	0.97
	1994	0.98	0.98
Tobacco	1989	0.77	-
	1990	0.75	1.02
	1991	0.73	1.02
	1992	0.70	1.04
	1993	0.67	1.04
	1994	0.64	1.04
Textiles	1989	0.95	-
	1990	0.94	0.98
	1991	0.93	1.01
	1992	0.92	1.01
	1993	0.91	1.01
	1994	0.90	1.01
Leather	1989	0.86	-
	1990	0.88	0.97
	1991	0.89	0.98
	1992	0.90	0.98
	1993	0.91	0.98
	1994	0.92	0.98

Sector	Year	Mean Technical Efficiency	Mean Efficiency change
Wood	1989	0.98	-
	1990	0.98	1
	1991	0.96	1.02
	1992	0.94	1.02
	1993	0.90	1.04
	1994	0.84	1.07
Paper	1989	0.84	-
	1990	0.82	1.02
	1991	0.81	1.01
	1992	0.79	1.02
	1993	0.77	1.02
	1994	0.75	1.02

Table 6: The mean technical efficiency and efficiency change registered by each sector

5.3 The impact of finance constraints on technical efficiency change

In this subsection, I will explore the impact of finance constraints on technical efficiency change. The empirical approach reported in this section is an application of the idea that a firm with a limited access to external resources will generally have an incentive to improve its technical efficiency over time. The dependent variable is $\Delta u_{it} = -(u_{it} - u_{it-1})$. A positive value indicates that the firm is becoming more efficient: a negative value implies that the firm is allowing its technical efficiency to slip over time. Note that Δu is implicitly a first difference of log values: it is therefore appropriate to express all regressors as first differences in logs. The explanatory variables are of three types. The first type consists of different measures of the shadow cost of capital. As already written in the previous subsection, I proxy the shadow cost of capital by the debt to asset ratio and the interest coverage ratio. I expect the coefficients of these two variables to be positive. Indeed the higher the debt to asset ratio, the less external resources are available to the firm as a bank can regard the default's risk as too high. Therefore, a firm is supposed to improve its technical efficiency to gain in productivity. The same is true for the interest coverage ratio: a high value of the ratio implies that the debt burden is high for the firm and this limits its availability of external resources; again this impacts positively the change in technical efficiency the firm experiences.

The second kind of regressors reflects the fact that the technical efficiency change is related to the average gross investment rate of the firm over the period. In this sense, I follow the suggestion by Scott (1991) and Hay and Liu (1997) that the contribution of capital accumulation to the firm's technical efficiency change should be controlled by inserting the gross investment rate among regressors. Indeed this incorporates new techniques and therefore does more than merely replacing old capital. Indeed old capital stock may be scrapped not because it is "worn out" but because it is technically obsolete. In the equation to estimate, the gross investment rate is also squared to control for the return to scale in the relationship between the investment ratio and the efficiency change. Finally, the empirical equation is completed by introducing firm and year fixed effects. I would not expect the firm fixed effect to be significant since the equation is in first differences. Year dummies should pick up any cyclical effects, though should be noted that the estimated distance frontiers have already controlled for these effects with time-period dummies. The regression results are given in Table 7 for the interest coverage ratio and in Table 8 for the debt to asset ratio.

Sector	Variables	OLS	FE	RE
Extr. Met.	ICR	-0.0041	0.0006	0.0003
		(-0.048)	(0.011)	(0.007)
	Investment ratio	0.0020	-0.0179	-0.0150
		(0.070)	(-0.831)	(-0.718)
	Squared Inv. ratio	-0.0008	0.0008	0.0006
		(-0.842)	(1.128)	(0.844)
	Constant	0.9604	-	0.9606
		(16.28)	-	(10.23)
	Hausmann Test	0.00010	$\chi^2 = 9.35$	
	Wu Test	0.020	$F = 3.84$	
	N. obs=324			
Transf. Met.	ICR	0.93118	0.92864	0.78306
		(140.642)	(121.882)	(110.252)
	Investment ratio	0.0701	0.0728	0.0599
		(10.493)	(9.456)	(8.361)
	Squared Inv. ratio	-0.0011	-0.0011	-0.0009
		(-9.450)	(-8.444)	(-7.509)
	Constant	0.8282	-	0.8543
		(39.958)	-	(31.358)
	Hausmann Test	0.00010	$\chi^2 = 9.35$	
	Wu Test	0.033	$F = 3.84$	
	N. obs=1662			
Food Ind.	ICR	0.0066	0.0072	0.0068
		(1.904)	(2.219)	(2.112)
	Investment ratio	-0.0114	-0.0059	-0.0094
		(-1.236)	(-0.621)	(-1.046)
	Squared Inv. ratio	0.00009	0.00004	0.00007
		(1.100)	(0.545)	(0.928)
	Constant	0.9460	-	0.9457
		(29.57)	-	(24.96)
	Hausmann Test	0.00010	$\chi^2 = 9.35$	
	Wu Test	1.649	$F = 3.84$	
	N. obs=258			

Sector	Variables	OLS	FE	RE
Tobacco	ICR	0.0210	0.0204	0.0205
		(1.327)	(2.443)	(2.455)
	Investment ratio	0.0357	0.0134	0.0154
		(2.406)	(1.478)	(1.721)
	Squared Inv. ratio	-0.0041	-0.0007	-0.0011
		(-1.683)	(-0.530)	(-0.742)
	Constant	1.036	-	1.037
		(80.707)	-	(55.41)
	Hausmann Test	0.00010	$\chi^2 = 9.35$	
	Wu Test	1.086	$F = 3.84$	
	N. obs=486			
Textiles	ICR	0.0039	0.0046	0.0042
		(3.886)	(4.103)	(3.939)
	Investment ratio	0.00001	0.00009	0.00004
		(0.126)	(0.556)	(0.298)
	Squared Inv. ratio	-0.000005	-0.000008	-0.000006
		(-0.562)	(-0.695)	(-0.605)
	Constant	1.0095	-	1.0098
		(1.376)	-	(1.369)
	Hausmann Test	0.00010	$\chi^2 = 9.35$	
	Wu Test	1.369	$F = 3.84$	
	N. obs=270			
Leather	ICR	0.0018	0.0019	0.0019
		(1.786)	(2.869)	(2.850)
	Investment ratio	0.0001	0.0006	0.0007
		(1.261)	(1.071)	(1.190)
	Squared Inv. ratio	-0.000001	0.000009	0.000005
		(-0.444)	(0.413)	(0.258)
	Constant	0.9874	-	0.9874
		(85.719)	-	(52.405)
	Hausmann Test	0.00010	$\chi^2 = 9.35$	
	Wu Test	1.495	$F = 3.84$	
	N. obs=1410			

Sector	Variables	OLS	FE	RE
Wood	ICR	0.0653	0.0709	0.0679
		(2.913)	(3.440)	(3.305)
	Investment ratio	0.0041	-0.0016	0.0018
		(1.493)	(-0.547)	(0.671)
	Squared Inv. ratio	-0.00002	0.00002	-0.00003
		(-0.785)	(0.849)	(-0.105)
	Constant	1.031	-	1.032
		(55.987)	-	(48.011)
	Hausmann Test	0.00010	$\chi^2 = 9.35$	
	Wu Test	0.746	$F = 3.84$	
	N. obs=1368			
Paper	ICR	0.0086	0.0076	0.0077
		(1.313)	(1.764)	(1.795)
	Investment ratio	-0.0004	0.0007	0.0004
		(-0.642)	(0.139)	(0.001)
	Squared Inv. ratio	0.00001	-0.00001	-0.00008
		(0.200)	(-0.180)	(-0.127)
	Constant	1.024	-	1.024
		(169.093)	-	(110.163)
	Hausmann Test	0.00010	$\chi^2 = 9.35$	
	Wu Test	1.250	$F = 3.84$	
	N. obs=720			

Table 7: Finance constraints and technical efficiency change: second stage estimation

Note: ICR is the investment coverage ratio. Between parentheses, the t-ratios are reported. The data are unbalanced due to missing values. Dropping the insignificant independent variables makes no substantive difference to the coefficient on other variables. The regressions have been run by inserting firm- and time-fixed effects. The estimated coefficients are not shown but they are generally significant. The Hausmann test is the test to choose between the fixed and random effect model and it has been constructed as detailed in the text. The Wu test is to test for exogeneity of the interest coverage ratio and it has been constructed as detailed in the text.

Extr. Met.	DAR	0.7786	0.7726	0.7464
		(26.923)	(24.121)	(25.467)
	Investment ratio	0.2301	0.2366	0.2203
		(7.694)	(7.138)	(7.267)
	Squared Inv. ratio	-0.0830	-0.0870	-0.0795
		(-6.770)	(-6.329)	(-6.398)
	Constant	0.5963	-	0.6121
		(9.694)	-	(9.750)
	Hausmann Test	0.00010	$\chi^2 = 9.35$	
	Wu Test	0.283	$F = 3.84$	
	N. obs=324			
Transf. Met.	DAR	0.00006	0.00001	0.00009
		(0.742)	(1.280)	(0.978)
	Investment ratio	0.00001	0.00002	0.00001
		(0.416)	(0.547)	(0.479)
	Squared Inv. ratio	0.000001	-0.000003	-0.000001
		(0.031)	(-0.509)	(-0.220)
	Constant	1.0006	-	1.0003
	(0.167)	-	(0.178)	
	Hausmann Test	0.00010	$\chi^2 = 9.35$	
	Wu Test	1.499	$F = 3.84$	
	N. obs=1662			
Food Ind.	DAR	0.0978	0.1287	0.1079
		(2.669)	(2.981)	(2.689)
	Investment ratio	-0.0039	-0.0072	-0.0050
		(-0.290)	(-0.439)	(-0.339)
	Squared Inv. ratio	0.00006	0.00008	0.00007
		(0.550)	(0.687)	(0.590)
	Constant	0.9399	-	0.9396
		(23.739)	-	(18.544)
	Hausmann Test	0.00010	$\chi^2 = 9.35$	
	Wu Test	1.289	$F = 3.84$	
	N. obs=258			

Sector	Variables	OLS	FE	RE
Tobacco	DAR	0.0120	0.0084	0.0118
		(1.196)	(0.871)	(1.275)
	Investment ratio	0.0104	0.0273	0.0169
		(0.621)	(1.613)	(1.067)
	Squared Inv. ratio	0.0011	-0.0020	-0.0001
		(0.410)	(-0.742)	(-0.059)
	Constant	1.037	-	1.036
		(71.295)	-	(63.331)
	Hausmann Test	5.575	$\chi^2 = 9.35$	
	Wu Test	0.817	$F = 3.84$	
	N. obs=486			
Textiles	DAR	0.0076	0.0089	0.0081
		(9.352)	(9.385)	(8.981)
	Investment ratio	0.0001	0.0002	0.0001
		(0.980)	(0.977)	(0.935)
	Squared Inv. ratio	-0.000001	-0.000002	-0.000001
		(-1.232)	(-1.441)	(-1.249)
	Constant	1.0099	-	1.0095
		(86.230)	-	(86.162)
	Hausmann Test	0.00010	$\chi^2 = 9.35$	
	Wu Test	1.596	$F = 3.84$	
	N. obs=270			
Leather	DAR	0.0067	0.0073	0.0068
		(4.517)	(4.611)	(4.536)
	Investment ratio	0.00007	0.00007	0.00005
		(0.300)	(0.240)	(0.231)
	Squared Inv. ratio	-0.000001	-0.000001	-0.000001
		(-0.597)	(-0.433)	(-0.496)
	Constant	0.9871	-	0.9870
		(53.636)	-	(48.404)
	Hausmann Test	0.00010	$\chi^2 = 9.35$	
	Wu Test	0.947	$F = 3.84$	
	N. obs=1410			

Sector	Variables	OLS	FE	RE
Wood	DAR	0.0872	0.0851	0.0861
		(3.963)	(3.558)	(3.708)
	Investment ratio	-0.0076	-0.0092	-0.0082
		(-1.995)	(-2.145)	(-1.997)
	Squared Inv. ratio	0.00005	0.00006	0.00005
		(1.143)	(1.294)	(1.170)
	Constant	1.0352	-	1.0353
		(42.386)	-	(33.970)
	Hausmann Test	0.00010	$\chi^2 = 9.35$	
	Wu Test	0.622	$F = 3.84$	
	N. obs=1368			
Paper	DAR	0.0356	0.0310	0.0337
		(5.382)	(4.949)	(5.620)
	Investment ratio	0.0018	0.0019	0.0016
		(2.070)	(1.533)	(1.974)
	Squared Inv. ratio	-0.00002	-0.00003	-0.00002
		(-2.161)	(-1.424)	(-2.089)
	Constant	1.0222	-	1.0218
		(139.321)	-	(122.939)
	Hausmann Test	0.00010	$\chi^2 = 9.35$	
	Wu Test	0.388	$F = 3.844$	
	N. obs=720			

Table 8: Finance constraints and technical efficiency change: second stage estimation

Note: DAR is the debt to asset ratio. Between parentheses, the t-ratios are reported. The data are unbalanced due to missing values. Dropping the insignificant independent variables makes no substantive difference to the coefficient on other variables. The regressions have been run by inserting firm- and time-fixed effects. The estimated coefficients are not shown but they are generally significant. The Hausmann test is the test to choose between the fixed and random effect model and it has been constructed as detailed in the text. The Wu test is to test for exogeneity of the debt to asset ratio and it has been constructed as detailed in the text.

The two tables show the empirical results from the estimation of the two empirical models using the three different estimators, namely the Ordinary Least Squares (OLS), the Fixed Effect estimator (FE) and the Random Effect estimator (RE)[13]. The coefficient of the time fixed effects are not shown but they are generally significant. In addition, the results from the Hausmann test and the Wu test are reported with the degrees of freedom for each estimated equation. The Hausmann statistics show that the preferred estimator to take into account the firms' heterogeneity is the Random Effect Estimator. The Wu statistics shows that the finance constraints have to be regarded as exogenous and therefore the causation relationship assumed in the model (that is, from the shadow cost of capital to the technical efficiency change) is correct.

Regression results are much as expected for both measures of shadow cost of capital. The variation of the Interest coverage ratio (ICR) is a positively significant variable for the Transformation of Metals sector, for the Food processing sector, for the Tobacco sector, for the Textile sector, for the Leather sector and for the Wood sector. Therefore, an increase in the debt burden for firms operating in these sectors has a positive impact on their technical efficiency change, though the coefficients are not large. However, this variable is not significant for the sector of Extraction of Metals and of Paper. The coefficient associated with the change in the debt to asset ratio is positive and significant for the sector of Extraction of Metals, for the Textiles, for the Leather sector, for the Wood sector, for the Paper sector and for the Food sector. Again, the increase of the debt on the total assets held by a firm has the effect of reducing the availability of external resources and therefore gains in productivity are allowed only by decreasing inefficiency over time. This is not verified for the sector of the Transformation of Metals and for the Tobacco sector.

Technical efficiency change is positively influenced by the change in the investment rate in the sectors of Transformation of Metals, of Extraction of Metals, of Tobacco, of Textiles, of Leather and of Wood but, as indicated by the negative coefficient on the quadratic term, this relationship is subject to diminishing returns. Technical efficiency change is negatively related with the change in the investment rate in the sectors of Food processing and Paper.

To sum up, there is support for the hypothesis that the technical efficiency change is affected by the availability of external financial resources; the tighter the finance constraints, the more efficient the firm gets over time.

[13]The equation have also been estimated by Two stage least squares by introducing lagged values of the finance constraints have been introduced. However, the new coefficient are not significant and therefore they have not been shown.

6 Concluding remarks

In this paper I have analyzed the effect of credit constraints on technical efficiency change, using a panel of firms drawn from the Italian manufacturing, covering the period 1989-1994.

In the last twenty years, there has been an increasing interest on the impact of asymmetric information on the optimal properties of the competitive equilibrium in the credit market and on firms' capital accumulation process. Thanks to some papers by Stiglitz and Weiss (1981) and Williamson (1986), the theoretical instruments aimed at analyzing trade under imperfect information has been extended to the study of the credit market. These works conclude that asymmetric information in the credit market create an incentive problem inducing banks to ration credit. Indeed, in both adverse selection and moral hazard, an increase of the interest rate on loans may adversely affect the rate of return to banks and therefore these may wish to hold the interest rate below the competitive level since raising it would lower their returns. Thus some borrowers will be rationed in equilibrium and they will not get enough financial resources to carry out their activities.

Afterwards, a complementary stream of literature has analyzed the implications of these informational imperfection on firms' investment activities; indeed a prediction from these models is that some classes of firms will not get the necessary resources to finance their investments. Therefore, the demand for investment of a rationed firm will depend positively on its balance sheet position as this implies that they have more available resources. This prediction has been tested extensively and it has found general support.

So far, however, to my knowledge, no empirical study has analyzed the impact of finance constraints on the firm's technical efficiency change. Indeed, it is reasonable to think that the availability of external resources can affect the efficiency of the productive process; as the firm cannot have access to additional resources to improve its technology and therefore there is no technical change it can experience and it will improve the efficiency over time to gain in productivity. Therefore, it is reasonably to expect that debt constrained firms will have a positive variation of technical efficiency over time.

This hypothesis on the relationship between finance constraints and technical efficiency change has been tested in this paper. More precisely, I have tested whether finance constraints create an incentive for debt-constrained firms to improve efficiency along time, using a sample of firms from the Italian manufacturing over the period 1989-1994. The work is divided into two parts: I have first considered theoretically the relationship between finance constraints and technical efficiency change. To this purpose, I have considered the efficiency change for a debt constrained and value maximizing firm and it has been contrasted it with the equivalent one for a non debt constrained one. The main prediction from this model is that finance constraints create an incentive for firms to improve efficiency. In the second stage, I have tested this prediction empirically, using a panel of firms from the Italian manufacturing. This panel has been drawn from the Mediocredito database. In particular I have chosen a sample of 1124 firms, covering the period 1989-1994 and organized in the main 8 sectors from the Italian manufacturing. The empirical analysis has been articulated itself into two stages: in the former, I have derived the indices of technical efficiency change by using a novel approach based on the estimation of a parametric stochastic distance function. Then, in the second stage, I have regressed the derived technical efficiency change indices on some indicators of finance constraints to analyze their impact on the efficiency growth of the sectors. Following a consolidated tradition in the empirical literature on credit constraints, these have been measured by the interest coverage ratio and the debt to asset ratio. The former variable is a measure of the firm's likelihood of financial distress relative to its fundamental health: the higher the ratio, the higher the probability of bankruptcy; the latter variable is usually interpreted as a measure of the firm's demand for borrowing relative to its debt capacity proxied by its market value. The results of the second stage show that there is support for the hypothesis that technical efficiency change is affected by the external resources availability; more precisely, once a firm is subject to stricter finance constraints than other firms, then it has an incentive to improve its technical efficiency over time to guarantee positive profits and gains in productivity.

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