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The relationship between firm size and efficiency: why does default on bank loans matter?

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Abstract
This paper presents an investigation of the interconnection between firm size and efficiency under the financial constraints lens. Specifically, we used the Data Envelopment Analysis (DEA) technique to measure the efficiency of a sample of large, medium-sized and small private Italian firms, using the firms' default risk as an undesirable output. Our findings indicate that larger companies perform better than medium-sized and smaller companies in terms of efficiency (across all business profiles), including default on bank loans. Based on indicators widely employed to characterize the bank-firm relationship, our study demonstrates the need to improve the efficiency of the Italian entrepreneurial system, consisting mainly of small companies, through their dimensional growth.

Keywords Credit risk · Data Envelopment Analysis · Efficiency · Firm size · Financial constraints

JEL classification G21 · G32 · L25

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1 Introduction

In this study, we explore the relationship between firm size and technical efficiency in Italian manufacturing and service firms under the lens of the financial constraints theory by using the Data Envelopment Analysis (DEA) technique. The size-efficiency relationship is a highly debated issue and object of divergent theoretical interpretations. On the one hand, small enterprises are considered less efficient than large ones both because, in a traditional view, they cannot take advantage of economies of scale and because, when viewed through a more evolutionary lens, they lack the resources (including human and financial resources) to compete in a market where product and process innovations are required (Audretsch 1999). On the other hand, the control-loss phenomenon states that increasing distortions in communication across successive hierarchical levels imply coordination problems in large companies, to the detriment of their efficiency (Williamson 1967). In essence, this inefficiency driver is linked to the "law of diminishing control", according to which *"the larger any organization becomes, the weaker is the control over its actions exercised by those at the top"* (Downs 1966, p. 109).

Views and theoretical interpretations are therefore mixed. More in detail, large firms, compared to small ones, seem to have access to more resources as well as more opportunities to capitalize on investments (such as training programs and technical innovations) for competitiveness, thanks to scale economies (Lundvall and Battese 2000). In contrast, small firms are exposed to resource constraints that lead them to adopt imitative business models and offer a narrow product portfolio (Lafuente et al. 2020), relying on production and market specialization that often accompanies cooperation with other firms to exploit scale economies (Fuchs and Kirchain 2010). Competitive weaknesses, if not properly managed, increase the firm's vulnerability to market conditions and competitors' actions, to the detriment of performance (West and De Castro 2001), and reduce the ability of firms to take new strategic actions (Arora and Cohen 2015). On the other hand, some scholars argue that small firms bring many benefits in terms of social welfare, including more efficient allocation of resources, smoother hierarchical control, more equality in income distribution among the population, and less underemployment. The last benefit is enabled by the use of labour-intensive technologies by small enterprises (Aggrey et al. 2010; Young 1991). In a nutshell, the institutional size allows accounting for the effects of technological differences, different workforce skills, greater or lesser diversification of products and services, investment opportunities, forms of cooperation among firms, and numerous other size-related factors (Berger and di Patti 2006; Wijesiri et al. 2017), without reaching a clear and unambiguous conclusion on the relationship between size and efficiency.

These different theoretical interpretations are accompanied by conflicting empirical results from research in this strand. The literature on the relationship between efficiency and firm size spans different geographic areas, as well as different industries. The geographic areas mainly cover European countries (such as Germany, investigated by Badunenko 2010, and Schiersch 2013, and Spain, on which the studies by Diaz and Sanchez 2008, and Gumbau-Albert and Maudos 2002, focus), although some research considers non-European countries (such as East Africa, in Aggrey et al. 2010) or transcontinental countries (such as Turkey, in Taymaz and Saatçi 1997, and Taymaz 2005). Sample industries also vary, ranging for instance from the mechanical engineering industry (Schiersch 2013) to the chemical (Badunenko 2010), electrical (Yang and Chen 2009), financial (Wijesiri et al. 2017) and

manufacturing sectors (Diaz and Sanchez 2008; Gumbau-Albert and Maudos 2002; Taymaz 2005).

Some studies have found a negative linear relationship between efficiency and firm size (Diaz and Sanchez 2008), while most studies highlight a positive linear relationship (Badunenko 2010; Gumbau-Albert and Maudos 2002; Taymaz 2005; Wijesiri et al. 2017; Yang and Chen 2009). Other studies pointed out that the size-efficiency relationship is not monotonically increasing/decreasing. They have found U-shaped (Schiersch 2013) or inverted U-shaped (Aggrey et al. 2010; Biggs et al. 1996) relationships: in the first case, small and large enterprises are efficient, while medium-sized enterprises have on average the highest inefficiencies; on the other hand, in the second case, efficiency increases until a certain threshold of firm size is reached, and then decreases as firm size increases, so the relationship is negative for large firms and positive for small ones. The results by Lundvall and Battesse (2000) also confirm that the relationship between firm size and efficiency takes on mixed patterns. These ambiguous findings may be due to many factors, like different dimensional definitions that are used in the studies or different compositions of samples, often comprising only small and large groups of companies, excluding medium-sized ones.

In our study, we analyse this relationship within the credit risk framework, more specifically in the context of the financial constraints theory (see Sect. 2), employing significant indicators in the bank-firm relationship: financial and economic ratios as well as a default measure, namely days past due. Specifically, we consider a default to have occurred if the company in our sample was past due by more than 90 days for any credit obligation to one or more banks with which it had a relationship.

This research contributes to the debate on the size-efficiency relationship in several ways. Firstly, we use a very large dataset (over 10,000 firms), which includes firm-level data that are not publicly available and are very difficult to find (such as information about a company's default risk). Secondly, unlike other studies, our sample mainly consists of small firms, reflecting the size characteristics of the Italian production system, which is characterized by the extensive activity of small firms. Thirdly, we include the category of medium-sized enterprises (2,006 enterprises), which is often overlooked in previous studies. Fourthly, in the DEA model, we use a factor (i.e., days past due) as an undesirable output that, to the best of our knowledge, has not yet been employed, allowing us to study the size-efficiency relationship in the context of the bank-firm relationship and linked financial constraints for non-financial firms. This measure is very relevant to our study, as the literature agrees that larger firms are less likely to default than others (Antunes et al. 2016). Finally, for each group size, we examine all indicators used in the DEA model according to the different efficiency levels obtained.

Our results confirm the positive relationship between size and efficiency: larger enterprises are more efficient across all profiles investigated (capital strength, economic-financial performance and relationship with lending banks). They align with and contribute to the existing literature on the firm size-efficiency relationship, such as the resource-based view theory, which posits that larger firms may have access to more and diverse resources, which in turn leads to improved efficiency (Penrose 1959) or the learning-by-doing theory, which suggests that larger firms, due to their extended market experience, are more efficient (Arrow 1962). They also challenge the school of thought that small firms are more innovative and flexible, thus more efficient (Acs and Audretsch 1990).

Our findings offer several relevant implications for managers, policymakers, and regulators. On the one hand, firms should be encouraged to invest in technology and innovation and to consider growth and scalability as important strategic goals. This could involve exploring potential mergers and acquisitions, seeking strategic partnerships, or expanding into new markets. On the other hand, policymakers should consider introducing measures to support the growth of SMEs, given their importance to the Italian economy and the potential benefits of increasing in size, such as offering tax incentives for mergers and acquisitions or providing grants or low-interest loans for expansion activities. While supporting business growth, it is important for regulators to ensure that competition is not adversely affected. As a consequence, close monitoring of mergers and acquisitions should be ensured to prevent the formation of monopolies or the introduction of measures to support new entrants to the market. For this reason, it is critical that future research continue to investigate these dynamics to provide more nuanced insights that can further guide managerial and policy decisions.

The rest of the paper is organized as follows. Section 2 outlines the theoretical background and main characteristics of the Italian business system in light of the credit risk framework for banks (known as the Basel framework) and related financial constraints on firms. Section 3 and Sect. 4 present the methodology and data, respectively. Section 5 describes the empirical results. Finally, Sect. 6 offers discussion and concluding remarks.

2 Theoretical background and hypothesis development

In this Section, we first illustrate the theoretical background underlying our research question and then describe the main features of the bank-firm relationship in Italy in order to better understand the relevance of the firm size in the context to which our study refers.

2.1 The theoretical framework

The background of our research is based on the financial constraints theory. Under this, the shortage of external financing and the onerous conditions connected with the granting of credit induce enterprises to finance investment projects primarily through recourse to internal financing sources. Thus, in the presence of financial constraints, the availability of internal cash flows steers investment projects. What matters for our purposes are the underlying reasons for financial constraints, to be understood as either difficulty in obtaining external financing or the possibility of drawing on external sources at onerous conditions in terms of, for example, higher interest rates, more collateral required and lower credit amounts. Among the possible reasons, the main one is the information asymmetry -between company managers and investors - on the investment projects for which the company requires financing (Akerlof 1970; Greenwald and Stiglitz 1990; Myers and Majluf 1984; Stiglitz and Weiss 1981; Wang et al. 2019). Market imperfections thus lead to financial constraints, the impacts of which are very significant. For example, Chodorow-Reich (2014) and Amiti and Weinstein (2018) have shown that shocks to the supply of external finance, which becomes more inelastic, explain between 30 and 50 per cent of changes in employment and aggregate investment.

Information asymmetries may be even more severe in the case of smaller companies (Stiglitz 1989). The investment projects of smaller companies, which are often younger,

are usually considered to be riskier, resulting in higher costs of financing from banks or on the capital market. Smaller companies also tend to have less collateral for loans, making them riskier in the eyes of investors. As a result, lenders tend to trust these companies less and, therefore, grant them less financing or apply more onerous conditions (Hennessy and Whited 2007). The characteristics of lower transparency, higher risk and higher vulnerability in times of crisis are thus at the origin of why firm size is an important determinant of financial constraints (Agung 2000; Bagella et al. 2001). In this vein, Hadlock and Pierce (2010), confirming the relevance of firm size as a predictor of financial constraints, have created an index of financial constraints based on firm size and age. Almeida et al. (2004), Baños-Caballero et al. (2014), Cleary (2006), Devereux and Schiantarelli (1990), Gilchrist and Himmelberg (1995), Kadapakkam et al. (1998), Whited and Wu (2006) also have proposed measures of financial constraints based on size, among other things. Referring to the Italian context, which is the focus of our study, Carpenter and Rondi (2000) find that young and small enterprises seem to face more stringent financial constraints.

The financial constraints theory allows us to understand the impact of external financing on firm-specific variables, including our undesirable output. Italian firms, mainly consisting of small and medium-sized (see Sect. 2.2), suffer from the effects of market imperfections and, hence, financial constraints. In light of the different severity of constraints according to firm size, we expect a higher efficiency of large firms, whose easier access to external financial resources -in terms of both amount and cost- should lower, all things being equal, the default on bank loans. Therefore, our research hypothesis is as follows:

> *Hypothesis 1:* In light of the different financial constraints according to firm size, large Italian firms are more efficient than small and medium-sized enterprises.

2.2 Firm-bank relationships in Italy

The Italian production system is largely characterized by small and medium-sized enterprises (SMEs[1]), which account for 5.3 million active companies, almost 99% of all companies in the country. Most of these companies are family-owned and highly specialised in a specific sector or region (European Union 2018). SMEs contribute to Italy's gross domestic product (GDP) by providing goods and services to large companies, domestic and foreign markets and the public sector. They employ around 82% of the country's workforce, are the country's leading exporters and play an important role in driving the Italian economy (European Union 2018).

The Italian government has implemented the National Recovery and Resilience Plan (Italian Government 2021) that seeks to focus on developing innovative products, increasing export opportunities, and improving access to credit for small businesses. In addition, the Italian government created a directory of state services for SMEs (e.g., Invitalia Agency) that provides information and guidance on how to access resources, including financing and loans. Finally, the Italian government has created a network of research and development

[1] According to the definition provided by the European Union, firms with fewer than 250 employees and sales of less than 50 million euros (or an annual balance sheet total below 43 million euros) are considered to be SMEs (European Union 2018).

centres, which provide support to SMEs in developing new products and expanding their market share (OECD 2021).

The Italian production system is heavily dependent on bank credit to finance investments, which has led the banks to assume a key role in providing companies with the financial resources they need to carry out their activities. The banking sector also plays an important role in providing companies with services to access capital markets through the issuance of bonds or shares (including advisory and securities placement services).

When the effects of the 2008 financial crisis significantly affected the Italian economy, the structural limits of a strongly SME-oriented production system were confirmed, particularly in terms of access to credit and, consequently, medium-term resilience. Exogenous economic crises produce shocks in the global and local banking systems and, since SMEs are highly dependent on external sources of financing, this causes a disruption of financing for these enterprises (Berger and Udell 2002).

The ability of Italian firms to invest and finance themselves has been deeply influenced by the Basel framework, which set several constraints for banks to ensure the long-term stability of the entire credit system. The Basel framework (BCBS 2023) is a set of international banking regulations that settled minimum requirements for banks' capital and liquidity. The purpose of the framework is to protect the financial system by helping to promote a more stable and resilient banking sector (Fraisse and Thesmar 2020).

Over the last decade, the application of the Basel framework has forced the Italian banking sector to redefine its overall level of capitalization, with particular reference to local banks that play a significant role in guaranteeing small businesses access to the credit they need to invest and grow. Local banks, rooted in their local area, have small businesses as their usual customers, thus configuring a financial system defined as "bank-centric", underlining the close relationship between banks and firms.

The dependency of SMEs on bank credit, together with the stringent regulatory requirements on banks, have been affecting the supply of credit for a long time. On the one hand, the higher opacity of small enterprises compared to larger ones tends to increase screening and monitoring costs for banks, as well as to increase uncertainty about the estimated levels of their default probability. On the other hand, during the double recession of 2008–2013, banks have and are still tightening their lending policies to reduce the riskiness of their assets (Finaldi Russo et al. 2022). The result has been a major shift in the supply of new loans from smaller to larger firms, with a parallel increase in the risk of default for small firms. Therefore, financial constraints have been exacerbated for small and medium-sized enterprises. Indeed, studies on access to credit in times of financial difficulties converge in stating that all enterprises - large, medium-sized and small - face greater difficulties in accessing finance due to the stricter conditions applied by banks, which tend to adopt a more cautious approach in granting loans, including more stringent collateral requirements. As a result, total bank credit growth rates slow down (Çolak and Öztekin 2021; Greenwald et al. 2020), especially in banks with little room above regulatory buffers (Couaillier et al. 2022). In this context, SMEs, in particular, suffer from a suboptimal allocation of loans in terms of both lower lending and higher lending rates (Berger and Udell 2006; Cole and Sokolyk 2016; Degryse et al. 2018). This scenario implies a lower probability of default for larger firms than for others (Antunes et al. 2016).

3 Methodology

In this work, we use the DEA technique for measuring the relative efficiency (Farrell 1957) of a set of homogeneous units, known as decision-making units (DMUs), which typically perform the same function, by using the same set of inputs to produce the same sets of outputs. Set as a non-parametric method, DEA builds the efficiency frontier empirically from observed input and output data by means of linear programming techniques, thus avoiding the danger of specifying an incorrect functional form for the production frontier. DEA can also handle multiple inputs and multiple outputs at the same time, as well as can give information about peer units (the reference set) for each inefficient unit.

In a process with several inputs and outputs, efficiency is defined as the ratio between the weighted sum of outputs and the weighted sum of inputs. DEA solves the problem of the choice of weights by introducing a particular weighting system for every single DMU. According to Charnes et al. (1978), the maximum efficiency for a DMU j_0 being analysed can be calculated by solving the following CCR (Charnes, Cooper, Rhodes) model:

$$e_0 = \max \frac{\sum_{r=1}^{s} u_r y_{rj0}}{\sum_{i=1}^{m} v_i x_{ij0}} \tag{1}$$

$$\frac{\sum_{r=1}^{s} u_r y_{rj}}{\sum_{i=1}^{m} v_i x_{ij}} \leqslant 1, \tag{2}$$

$$u_r, v_i \geqslant 0 \tag{3}$$

where n is the number of units; m is the number of inputs; s is the number of outputs; u_r is the weight given to output j; and v_i is the weight given to input i.

This model maximizes the ratio of the weighted sum of outputs to the weighted sum of inputs for DMU j_0, subject to the constraint that the same ratio for other n DMUs in the sample should not exceed unity. It provides an efficiency score, bounded between 0 and 1, for each unit, as well as the subsequent ranking of the units in the sample examined. According to Farrell's definition, DMU j_0 efficiency will either be equal to l (if it is technically efficient relative to the other units in the sample) or will be less than l (if it is relatively inefficient).

DEA models can be divided into input-oriented models and output-oriented ones: the former analyses the potential improvement of resource utilization and the latter analyses the potential improvement of produced outputs, by measuring the relative efficiency of each DMU in terms of maximal radial contraction to its input levels or expansion to its output levels feasible under efficient operation, respectively. Besides, DEA satisfies both constant returns to scale (CRS) and variable returns to scale (VRS). Banker et al. (1984) have shown that the CCR model (which accounts for CRS) yields an evaluation of overall technical efficiency: the efficiency score obtained from the CCR model can,

in fact, be deconstructed into two components, one relating to scale efficiency and one relating to pure technical efficiency (Gastaldi et al. 2020).

In this study, we compute the technical efficiency of each firm by implementing a DEA model which accounts for variable returns to scale (VRS) of activities. We also focus on the output orientation of the model because, in this context, we assume that the efficiency of a production process entails the generation of desirable outputs from inputs used. Hence, firms that produce fewer outputs than others with the same input levels are relatively inefficient (Peda et al. 2013).

Hence, in our empirical analysis we use the extended model introduced by Banker et al. (1984) to account for VRS. The envelopment formulation of the model (named BCC from the authors' initials Banker, Charnes and Cooper) is as follows:

$$e_0 = \max \varphi_0 \tag{4}$$

subject to

$$\sum_{j=1}^{n} \lambda_j x_{ij} \leqslant x_{ij0} \tag{5}$$

$$\varphi_0 y_{rj0} - \sum_{j=1}^{n} \lambda_j y_{rj} \leqslant 0 \tag{6}$$

$$\sum_{i=1}^{n} \lambda j = 1 \tag{7}$$

$$\lambda_j \geqslant 0 \tag{8}$$

where y_{rj} is the amount of the r-th output ($r=1, \ldots, s$) for unit j ($j=1, \ldots, n$); x_{ij} is the amount of the i-th input ($i=1, \ldots, m$) for unit j; λ_j are the weights of unit j; and φ_0 is the scalar expansion factor for the DMU j_0 examined.

In this study, we also consider a third kind of factor, an undesirable output, to consider the default situation for each firm. Undesirable outputs must be handled differently from desirable outputs (Rapposelli and Za 2020): they need to be modelled as bad outputs (Barra et al. 2016) and, therefore, reduced. To this purpose, we use an alternative approach in dealing with desirable and undesirable outputs, which are incorporated into the linear programming model as inputs that need to be radially reduced (Coli et al. 2011). Hence, the BCC formulation introduced above was modified by adding the following constraint to the input side of the model:

$$\sum_{j=1}^{n} \lambda_j h_{tj} \leqslant h_{tj0} \tag{9}$$

where h_{tj} is the amount of the t-th undesirable output ($t=1, \ldots, z$) produced by unit j.

4 Data and variables

4.1 Sample

We employ a dataset of privately held Italian small, medium-sized and large enterprises operating with cooperative banks. Mutual banks mainly operate within a narrow geographical area (in Italian "zona di competenza territoriale", ZCT) and grant credit primarily (at least 50%) to their shareholders. Besides, they must concentrate at least 95% of their risky assets (loans and mortgages) on counterparties located in their ZCT. Firms or households may become a shareholder of a mutual bank only if they are based in the ZCT of the bank (Banca d'Italia 2013).

We use a database provided by an Italian credit rating agency (Centrale Rischi di Intermediazione Finanziaria - CRIF), containing detailed information, derived from different data sources, on large, medium and small Italian companies: financial and economic ratios derived from balance sheets, loan-level information on all relationships between firms and Italian banks derived from the "Centrale dei Rischi" (a credit register that lists all loans granted by banks operating in Italy), and personal data (i.e., sector of activity, geographical location and legal form). We collected data on economic, financial and default items; in our study, according to Basel rules, a default was considered to have occurred if the obligor was late by more than 90 days in respect of any material credit obligation (Modina and Pietrovito 2014).

After dealing with missing data and outlier observations[2], we obtain a sample of 10,169 manufacturing and service firms. With regard to outliers, efficiency results from the DEA method are contingent upon the homogeneity assumption of the set of firms to be analysed; the homogeneity criterion implies that there are no outliers in the sample (Peda et al. 2013). The firms in the sample operate in different Italian geographical areas and differ in size. To respect the homogeneity assumption for DMUs being analysed, we group them according to their size and geographical location (North-West, North-East, Centre, South and the islands, in accordance with the Italian National Institute of Statistics classification). Hence, our empirical analysis focuses on large (469), medium-sized (2,006) and small firms (7,694) primarily located in the North-East of Italy (77.64%).

Table 1 presents the composition of the sample depending on the firm size. The table also reveals that firms in default (11.01% of the total sample) are almost equally distributed in the three size classes, showing a higher concentration in the group of medium-sized firms (13.41%). The group of small firms shows the lowest percentage of enterprises that have invested in the share capital of cooperative banks (38.45% against 41.39% of the total sample).

[2] Our dataset was built following several steps. We carried out a careful analysis of the data quality of 747,606 initial balance sheets to identify three main types of problems: duplicate balance sheets, controls on balance sheet items and companies with "non-evaluable" balance sheets. We then analyzed the frequency distribution to determine outliers and other anomalies for all variables and made a final judgement on the quality of the balance sheets.

Table 1 Sample composition

	Large firms		Medium-sized firms		Small firms		Total	
	No.	%	No.	%	No.	%	No.	%
Geographical area								
North-East	378	80.6%	1,579	78.71%	5,938	77.18%	***7895***	***77.64%***
North-West	38	8.1%	164	8.18%	592	7.69%	***794***	***7.81%***
Central Italy	40	8.53%	185	9.22%	715	9.29%	***940***	***9.24%***
Southern Italy	11	2.35%	72	3.59%	395	5.13%	***478***	***4.7%***
Islands	2	0.43%	6	0.3%	54	0.7%	***62***	***0.61%***
Default event								
Yes	44	9.38%	269	13.41%	807	10.49%	***1120***	***11.01%***
No	425	90.62%	1,737	86.59%	6,887	89.51%	***9049***	***88.99%***
Shareholder								
Yes	261	55.65%	990	49.35%	2,958	38.45%	***4209***	***41.39%***
No	208	44.35%	1,016	50.65%	4,736	61.55%	***5960***	***58.61%***
Tot. sampled firms	**469**		**2,006**		**7,694**		***10169***	

Source: Authors' elaboration

4.2 Variables

The DEA method does not provide any suggestion to identify the most appropriate input-output set to be used in an efficiency assessment. Hence, in the selection of the input-output system, emphasis should be given to what is postulated by efficiency theory and what is indicated in the context under analysis (Agovino and Rapposelli 2013).

In order to model the relative efficiency of the three sets of homogeneous DMUs (large, medium-sized and small firms), we select as inputs nine economic and financial indicators, not correlated among them, according to their ability to investigate essential aspects of a company's economic and financial profile, such as profitability, asset management, leverage and liquidity[3] (Ricca et al. 2023). As output, we consider the return on assets (ROA), which is a well-known measure of profitability (Muhammad et al. 2016). Finally, to consider the default situation for each firm, we include a third kind of variable, an undesirable output, represented by the total amount of days past due.

More specifically, the nine input variables are represented by:

- **Debts on net worth**.

  It is a debt ratio constructed as the ratio of total debt to equity. It thus describes the weight of debts on equity (how much the company has had to borrow externally), and indicates the company's level of financial autonomy. It is also an indicator of low structural soundness in the face of excessive financial burden (the higher the value of the ratio, the higher the debts and thus the firm risk).

- **Quick ratio (Liquid assets on current liabilities)**.

[3] We built a long list of 60 balance-sheet variables through mapping of the available balance sheets, ending up (having excluded those with insufficient data quality and after performing a data analysis and correlation analysis) with a short list of nine unrelated indicators with high forecasting power.

This variable is constructed as the ratio of immediate liquidity (short-term receivables and cash on hand) to short-term payables. Thus, it describes the company's short-term financial balance, i.e., how many short-term debts are covered with immediate cash on hand (the higher the value of the ratio, the lower the risk because the more cash on hand).

- **Financial interests on added value**.

  It is an index of financial riskiness constructed as the ratio of financial expenses (interest expense and other financial charges) to value added. Very high values of this variable represent an indication of a company's financial weakness because the income generated from sales is largely absorbed in the repayment of debt capital.

- **Working capital turnover**.

  It is a measure of a company's efficiency in managing its short-term assets and liabilities. It is calculated by dividing the company's net sales by its average working capital. Working capital turnover is an important indicator of a company's financial health and can be used to compare the performance of different companies.

- **Inventory duration (inventory on the average daily cost of goods sold)**.

  This variable is constructed as the ratio of inventories to sales, multiplied by 365 (the result is expressed in days) and describes the firm management of inventory, indicating how quickly the firm can sell inventories/stocks and thus expressing the ability of the inventory to renew itself to produce revenue. In detail, the more days that pass, the more unbalanced the company is since too much has been produced compared to what is actually sold. The current trend is to keep as little inventory in stock as possible (just-in-time policies improve efficiency as they result in lower inventory costs and lower finance costs for inventory investment).

- **Turnover (Value of production on total assets)**.

  It is a measure of a company's efficiency in using its assets to generate revenue. It is calculated by dividing the total value of production by the total assets of the company. A high turnover ratio indicates that the company is more efficient in using its assets to generate revenue.

- **Unit cash flow (on total revenues)**.

  It is an index of income statement composition constructed as the ratio of cash flow to revenues. It describes, therefore, how much of the revenues produced the company manages to turn into cash, once costs are subtracted. In summary, the higher the value of the index, the more cash the company generates from revenues, thus the lower the risk; conversely, a low value of this variable (which equates to low cash flow

produced) indicates a particularly risky situation for the company because production costs are high resulting in low profit and therefore a situation of financial imbalance.

- **Shareholders' equity on long-term equity and payables**.

  It is a debt ratio constructed as the ratio of net worth to the sum of net worth and long debts. It describes, therefore, how much long debts weigh on the net capital; in detail, a low value of the ratio implies that medium/long debts affect total liabilities and therefore will have to be covered either with new debts or with a new capitalization or with increases in revenues. This variable is therefore also an indicator of structural soundness given that equity must not be underbalanced relative to debt (the higher the ratio value, the lower the risk because the greater the financial autonomy).

- **Payables to suppliers on net worth (shareholders' equity)**.

  It is a debt ratio constructed as the ratio of total debts to suppliers to shareholders' equity. It describes, therefore, how much the company owes to its suppliers relative to its equity: the higher the value of this ratio, the more unbalanced the company is (thus the greater the risk) because it is covering its assets with debt and not with equity.

Table 2 summarizes the three groups of variables and Table 3 presents the descriptive statistics of these variables (mean-M and standard deviation-SD), distinguishing between large, medium-sized and small firms.

The descriptive statistics listed in Table 3 show that large firms, in general, perform better than medium-sized and small firms. The first ones show higher profitability and a lower number of days past due. Besides, they show a lower quick ratio (107.4136) than medium-sized and small firms (122.9069 and 121.4427, respectively), but this value could

Table 2 Description of variables

Variables group	Variables definition	Type of ratio
Inputs	Debts on net worth	Debt ratio
	Quick ratio (Liquid assets on current liabilities)	Short-term liquidity ratio
	Financial interests on added value	Financial ratio
	Working capital turnover	Asset management ratio
	Inventory duration (inventory on the average daily cost of goods sold)	Asset management ratio
	Turnover (Value of production on total assets)	Asset management ratio
	Unit cash flow (on total revenues)	Liquidity ratio
	Shareholders' equity on long-term equity and payables	Debt ratio
	Payables to suppliers on net worth (shareholders' equity)	Debt ratio
Output	ROA (Return on Assets)	Profitability ratio
Undesirable output	Days past due	Default indicator

Source: Authors' elaboration

Table 3 Descriptive statistics

		Cash flow on total revenues	Debts on net worth	Payables to suppliers on net worth	Inventory duration	Quick ratio	Financial interests on added value	Shareholder equity on long-term equity and payables	Working capital turnover	Turnover	ROA	Days past due
		Profitability ratio	*Debt ratio*	*Debt ratio*	*Asset management ratio*	*Liquidity ratio*	*Financial risk ratio*	*Debt ratio*	*Asset management ratio*	*Asset management ratio*	*Profitability ratio*	*Default indicator*
Large	M	7.79	511.84	191.3169	110.47	107.4136	4.8641	62.5795	334.7863	122.6976	12.1151	7.7733
	SD	9.76	714.2474	296.3059	172.76	130.1823	3.9956	27.7683	405.1059	89.1191	4.5305	46.7094
Medium	M	7.67	707.6079	216.6185	148.02	122.9069	5.4992	58.921	296.1195	103.5613	11.1369	19.723
	SD	9.05	1020.0814	327.4126	213.29	161.3129	5.0146	29.8424	395.1407	83.8801	4.5216	98.0318
Small	M	8.17	927.2376	263.0272	144.26	121.4427	5.7086	53.3182	348.462	105.2614	11.6072	19.4281
	SD	9.79	1201.7668	365.5082	214.39	161.557	5.3175	32.3722	458.6852	82.253	5.184	99.556

Source: Authors' elaboration

be interpreted positively, in the sense that large firms prefer to have less liquid assets as a non-interest-bearing item. Medium-sized companies present some critical values in terms of asset management (i.e., duration of stocks and working capital turnover). Finally, small businesses do not show a regular pattern: They seem to excel in cash generation and working capital management, while they have a weaker financial structure (they display a low capitalisation and a high debt), with consequent negative effects on financial interests, which register a high incidence on added value. The data confirm that small Italian enterprises are heavily reliant on bank credit, which is why the Italian financial system is often referred to as "bank-centric". This reliance on bank credit can be seen in the high levels of borrowing by small Italian businesses, as well as the large share of bank loans in total financing for these businesses (Banca d'Italia 2022).

5 Empirical results

We apply the efficiency concept described above to our sample. We perform the efficiency analysis using Max-DEA software. For each firm, we compute an output-oriented DEA efficiency score. Table 4 presents the descriptive statistics for the efficiency scores obtained.

The DEA model results show quite significant differences among the three groups analysed (large, medium-sized and small firms). As illustrated in Table 4, the average efficiency score registered for large firms (equal to 0.938) is higher than the ones registered for medium-sized (0.8279) and small (0.7528) firms, whereas the score variability is lower. A substantial homogeneity in the distribution of DEA scores is registered across firms' geographical areas, i.e. the efficiency scores are very similar for the five macro-zones considered (see Table 1). Besides, we have not found significant differences in the efficiency scores registered also by considering the presence of shareholders among the firms analysed[4].

Based on the efficiency values, we classify the evaluated units into four groups: fully efficient DMUs (units with an efficiency score equal to 1), highly efficient DMUs (an efficiency score bounded between 0.7 and 0.99), moderately efficient DMUs (an efficiency score bounded between 0.5 and 0.7) and low efficiency DMUs (an efficiency score of less than 0.5) (Table 5).

By focusing on the best performers, we observe that in the large enterprises' group, the percentage of fully efficient DMUs (equal to 66.1) is higher than the percentages registered for medium-sized firms (41.3) and small (31.1) firms. Furthermore, we note that the percentage of DMUs with an efficiency score above 0.7 is higher in the large enterprise group (94.9, compared to 79.1 for medium-sized and 60.5 for small firms). In contrast, by observing less efficient units, the percentage of firms with an efficiency score value of less than 0.5 is found to be higher in small firms (14.3, compared to 2.8 for large firms and 8.9 for medium-sized firms) (Table 5). These results suggest that large firms operate with a high level of efficiency, while many small firms do not operate with optimal efficiency.

Tables 6, 7 and 8 list, for each group size, the average values for each DEA variable, i.e. inputs and outputs (both desirable and undesirable) included in our DEA model, computed for the four efficiency levels considered above.

[4] DEA efficiency scores registered for the five macro-areas and by considering the presence of shareholders are available on request.

Table 4 Summary statistics for DEA efficiency score by group size

	Large firms	Medium-sized firms	Small firms
No. of fully efficient units	310	828	2,394
Mean	0.938	0.8279	0.7528
Standard deviation	0.1327	0.2312	0.2516
Minimum	0.0023	0.0005	0.0003
Maximum	1	1	1

Source: Authors' elaboration

Table 5 DEA efficiency score by levels

	Large firms		Medium-sized firms		Small firms	
	No.	%	No.	%	No.	%
Efficiency score = 1	310	66.1%	828	41.3%	2,394	31.1%
0.7 < efficiency score ≤ 0.99	135	28.8%	758	37.8%	2,265	29.4%
0.5 < efficiency score ≤ 0.7	11	2.3%	241	12%	1,936	25.2%
Efficiency score ≤ 0.5	13	2.8%	179	8.9%	1,098	14.3%
Total firms	469		2,006		7,693	

Source: Authors' elaboration

It can be seen that efficient large firms (those with an efficiency score higher than 0.7) present efficient working capital management, a high value of liquid assets on current liabilities and good performance in terms of generation of both income (ROA) and financial (cash flow on total revenues) flows. In contrast, less efficient large firms (with an efficiency score value of less than 0.5) present weaknesses in both economic and financial profiles, except turnover (Table 6).

By focusing on medium-sized firms, we find that firms with an efficiency score higher than 0.7 present good values only for ROA, turnover, working capital turnover and quick ratio. Less efficient firms show the worst values with regard to capital adequacy (i.e., there is a high level of debt in comparison with equity) and economic performance (ROA). This situation highlights some difficulties in the relationship between firms and banks, as shown by the high number of days past due at the lowest efficiency level (74.43 days), compared to other efficiency levels (Table 7).

Finally, small firms exhibit a "polarization" of results (Table 8). The most efficient ones (with a score equal to 1) show many more strengths than weaknesses, while the least efficient ones (a score below 0.5) experience the opposite situation, i.e., they have many critical points and few satisfactory performances. A curious note is the specularity between these two groups of small enterprises: where the least efficient firms display the highest values of two ratios (shareholders' equity/long-term equity and payables and turnover), the most efficient ones show the lowest values. A similar, but opposite, situation is evident with regard to other variables expressing economic and financial performance (ROA, cash flow/revenues and financial interests on added value): the most efficient firms show the best performance, and the least efficient show the worst.

The presented results confirm our research hypothesis and are in line with previous studies that have underlined the greater efficiency of large companies (Penrose 1959; Arrow 1962; Badunenko 2010). Our paper proves this behaviour while also considering default risk as an undesirable output. The variable "days past due" shows the highest values in all size categories of enterprises with the lowest efficiency scores, underlining how efficiency is

Table 6 Mean values of DEA variables by efficiency level – large firms

	Cash flow on total revenues	Debts on net worth	Payables to suppliers on net worth	Inventory duration	Quick ratio	Financial interests on added value	Shareholders' equity on long-term equity and payables	Working capital turnover	Turnover	ROA	Days past due
Eff. score = 1	8.8394	525.9326	192.2631	114.1571	117.0817	4.9086	56.7645	388.2178	116.3859	12.2828	7.831
0.7 < eff. score ≤ 0.99	5.7186	443.8413	176.579	109.827	89.8887	4.6218	74.8666	231.4118	135.0941	12.5448	6.9785
0.5 < eff. score ≤ 0.7	6.4618	392.8136	168.6736	70.4236	85.24	4.6018	75.29	203.6309	127.6791	10.3655	0.3636
Eff. score ≤ 0.5	5.4492	982.8123	340.9615	63.2438	77.6192	6.54	62.8915	245.1331	140.2585	5.1338	20.9231

Source: Authors' elaboration

Table 7 Mean values of DEA variables by efficiency level – medium-sized firms

	Cash flow on total revenues	Debts on net worth	Payables to suppliers on net worth	Inventory duration	Quick ratio	Financial interests on added value	Shareholders' equity on long-term equity and payables	Working capital turnover	Turnover	ROA	Past due [days]
Eff. score = 1	9.3886	707.1656	175.378	179.2232	152.5418	6.0382	49.4195	376.4464	90.1226	11.7033	22.1048
0.7 < eff. score ≤ 0.99	5.8774	720.3885	261.3736	119.4098	112.1078	5.0073	66.5577	242.1328	122.1453	12.2406	9.1178
0.5 < eff. score ≤ 0.7	8.0751	534.2354	169.6960	108.675	96.2086	5.2923	65.6056	230.8208	87.637	10.8705	4.2775
Eff. score ≤ 0.5	6.7494	891.0796	281.9647	174.4741	68.0129	5.2575	61.5969	242.2325	108.9204	4.2123	74.4335

Source: Authors' elaboration

Table 8 Mean values of DEA variables by efficiency level – small firms

	Cash flow on total revenues	Debts on net worth	Payables to suppliers on net worth	Inventory duration	Quick ratio	Financial interests on added value	Shareholders' equity on long-term equity and payables	Working capital turnover	Turnover	ROA	Past due [days]
Eff. score = 1	10.6468	869.1113	197.218	149.5961	161.2266	5.648	42.5441	497.3993	89.6236	12.8792	17.6540
0.7 < eff. score ≤ 0.99	7.7439	1104.0335	305.0594	170.265	112.7327	5.962	53.1763	302.1131	105.7354	12.7395	22.0091
0.5 < eff. score ≤ 0.7	6.6315	803.1013	272.5675	116.3601	102.1954	5.3502	61.7476	258.3425	110.4686	11.6151	13.3699
Eff. score ≤ 0.5	6.3995	908.9152	303.1483	128.2759	86.5927	5.9543	62.1968	278.4047	129.1893	6.4826	28.6713

Source: Authors' elaboration

a key variable in the fulfilment by borrowed enterprises of their commitments to banks. Furthermore, the DEA method reveals that the higher efficiency of large firms is significantly present in almost all aspects of business management. This finding reinforces the idea that growth strategies may be the best way for Italian businesses to improve their economic and financial performance. Growth strategies can involve expanding into new markets, introducing new products or services, or investing in new technologies. By taking these steps, businesses can increase their revenues and profits, and become more competitive in the global marketplace.

6 Discussion and conclusion

The firm size-efficiency relationship is a topic that is debated at both theoretical and empirical levels. The relevance of this issue is even greater in countries where the production system is characterized by the prevalence of small enterprises, as in the case of Italy. In this case, the "size issue" of the production system, that is, the so-called "dwarfism" of firms, is still at the attention of regulatory and governmental authorities, with significant implications in terms of innovation and intangible capital (Bugamelli et al. 2012).

Our results indicate that in Italy (and most likely in other countries similar in dimensional characteristics of the production system), larger companies perform better than smaller ones. Larger enterprises demonstrate more efficiency across all profiles investigated, including capital strength, economic-financial performance, and relationships with lending banks. This can be interpreted within the framework of the financial constraints theory, as larger companies are more likely to have access to both internal and external sources of financing, which enables them to invest in efficiency-enhancing technologies or strategies. Furthermore, larger firms are less likely to default, which may lead to more favorable terms from banks, reducing their financial constraints. One significant contribution of our study is the inclusion of default risk as an undesirable output in our DEA model. This is particularly relevant given that larger firms are less likely to default (Antunes et al. 2016). By controlling for default risk, we can better understand the relationship between firm size and efficiency. Our results suggest that even when accounting for the increased risk of default, larger firms are still more efficient than small and medium-sized enterprises.

Based on our findings, the need to improve efficiency is more pronounced in medium and small enterprises because of their contribution to the overall competitiveness of the business system. Thus, the dominance of smaller enterprises in the Italian production system should not be overlooked. While facing more significant financial constraints, these enterprises contribute to social welfare in various ways, such as providing employment and driving regional development. As a result, managers should prioritize enhancing operational and strategic efficiencies within these organizations. This may include investing in technologies and systems that streamline processes, enhancing employee training and skills development, and adopting best practices from larger, more efficient firms. The observed effects were found to persist even after the introduction of an undesirable output, namely firm default, which is a basic indicator in the Basel framework. This persistence suggests that company size is a crucial factor in managing business risk. Therefore, risk management strategies should consider firm size and the associated efficiency levels. It is important to understand the dynamics that determine company efficiency, and the differences between

size groups of companies, to stimulate the industrial plans of companies to promote growth, and to encourage supervisory authorities to introduce regulations and funding programmes in favour of company aggregations.

In light of the evidence suggesting that larger firms tend to be more efficient, managers and entrepreneurs should consider growth and scaling as strategic objectives. This might involve exploring opportunities for mergers and acquisitions, strategic partnerships, and expansion into new markets. Regulatory and governmental authorities should consider introducing regulations and funding programmes in favour of company aggregations. Such measures could help smaller firms to grow and compete more effectively. This could include tax incentives for mergers and acquisitions, grants or low-interest loans for expansion activities, and regulatory relief for larger firms.

To date much has been done, but more needs to be done. For example, the "bonus aggregazioni" has been introduced in the Italian legal system to provide a tax break for business aggregation operations, allowing firms to increase their size and compete more easily in the international market. The Industry 4.0 Plan (Ministero dello Sviluppo Economico 2022) is also a great opportunity for business growth, as it provides a set of organic and complementary measures that can encourage investment in innovation and competitiveness.

Alongside such public interventions, others aimed at providing capital for business growth will be needed. The spectrum of intermediaries other than banks - which are the main source of debt to Italian firms - is wide, ranging from debt funds to private equity funds, from crowdfunding to peer-to-peer lending, and from venture capital to public-private partnerships. Governments and regulatory authorities should work to ensure that these alternative sources of finance are made more accessible to small enterprises. The lack of openness of capital to outside investors plays a key role in the phenomenon of corporate "dwarfism" (Colli 2010; Cantele et al. 2016) as demonstrated by the negative correlation, recurring in the Italian market, between ownership concentration and corporate growth.

The findings of our research can be directly applied in practice. For instance, lending institutions can adjust their risk models to consider the size of a firm as an indicator of efficiency and default risk. Similarly, firms can use this information to justify growth strategies to stakeholders. Our results can also be used to influence policy. By demonstrating the efficiency advantages of larger firms, this research can provide a strong argument for policies that encourage firm growth.

Our study provides a solid basis for further research on the relationship between firm size and efficiency that could explore this relationship in more detail by examining factors such as industry, geographic location, and firm maturity. Future research could also examine the impact of policy interventions designed to encourage firm growth on efficiency and credit risk. This could include a comparative analysis of different types of interventions, such as tax incentives, grants, or regulatory relief.

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