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Full length article

**Firms' solidity before an exogenous shock: Covid-19 pandemic in Italy**

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**ABSTRACT**

In this paper we study the structural robustness of the Italian business system, using the Covid-19 pandemic as an exogenous event to test it. To this aim, we use the ROC (Receiver Operating Characteristics) methodology, quite new for economics, to classify Italian firms according to their economic solidity, obtaining a taxonomy based on a wide set of characteristics. Our results show that the number of “Solid” firms is less than one-fifth of all Italian enterprises but they represent the lion's share in terms of employment and value added. “Fragile” and “At Risk” firms, albeit much less relevant for the creation of value added, account for over one-third of total employment, so they may be a worrisome issue for policymakers. Solidity conditions have clearly both a size and sector-related dimension: At Risk and Fragile conditions prevail among firms of smaller economic size (a broad definition of firm size) and among those operating in Construction and Other services. Finally, we find that factors such as firms’ performance, and internal and external organization, although significant, play a less relevant role than economic size and digitalization/innovation in determining Italian firms' resilience to exogenous shocks such as the Covid-19 one.

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1. Introduction

The Covid-19 pandemic spread rapidly, affected people and economies across the world and pushed countries into the worst recession since World War II. However, the economic effects have been far from uniform: the severity of the impact has been different in timing and intensity across countries, industries, firms, and people (OECD, 2021).

This heterogeneity depended on several factors. As for industries and firms, administrative measures launched worldwide to limit the spread of contagion played a crucial role in hitting some economic activities hard and some others much less so, namely those considered essential by governments and therefore allowed to operate during lockdowns. However, also structural characteristics of industries and firms, such as their size, connection ability, and digital upskill, contributed to determining the strength of the economic impact of the pandemic.

More generally, the recovery prospects of a business system also depend on the choices undertaken by firms in pre-crisis years: they could be very different depending on whether past investments (e.g. in technology or human and intangible capital) turn out to be factors of resilience or not. For this reason, it is important to identify the structural and behavioral factors that can make firms, and therefore economies, more resilient to severe exogenous shocks like the one caused by Covid-19.

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This is the main goal of the paper. We adopt a multi-dimensional approach to the study of the structural solidity of the Italian business system, using the Covid-19 pandemic as an exogenous event to test it. Starting from the signals of operational risk reported by firms, a new taxonomy has been defined based on firm characteristics before the Covid-19 shock. In particular, we use a wide set of both structural-(economic dimension) and competitiveness-related variables (relational characteristics, composition and quality of the workforce, degree of innovation, and digitalization) to classify firms according to their solidity facing the crisis. Furthermore, to combine the need of dealing with a heterogeneous, multifaceted phenomenon and the necessity to provide a synthetic representation of it, we opted for a four-class taxonomy.

We propose an innovative application of the ROC (Receiver Operating Characteristics) methodology, iterating its typical binary classification of the sample to identify a four-class taxonomy of firms’ economic solidity: “Solid”, “Resistant”, “Fragile” and “At Risk”. The use of the ROC is quite new in economics, while it has been widely adopted in medicine (Lusted, 1960), and it is now a common standard of evaluation of medical and psychological tests (Pepe, 2003). Furthermore, ROC methodology is extensively used in machine learning (Majnik and Bosnić, 2013) and natural science (Warnock and Peck, 2010). To the best of our knowledge, so far in economics, this methodology has been used to test the accuracy of business cycle classification made by the Business Cycle Dating Committee of the National Bureau of Economic Research (Berge and Jordà, 2011) and in credit risk literature (Khandani et al., 2010). Furthermore, it has also been used to estimate the underground economy in National Accounts (Cavalli and Sallusti, 2019) and to determine firms’ export threshold, i.e. the minimum characteristics necessary for firms to access foreign markets (Costa et al., 2019, 2022).

As far as we know, no other works are trying to measure the solidity of a business system during the pandemic. However, at least two strands of literature are close to the aim of our topic: a) recent studies dealing with the economic impact of Covid-19, in particular, those trying to highlight the characteristics of industries and firms as factors of resilience/weakness to exogenous shocks; b) the analyses measuring the economic consequences of “natural disasters” (e.g., earthquakes, terrorism or cyberattacks).

As for the first strand, many recent papers try to measure the impact of Covid-19 on countries, industries, firms, and workers, whose heterogeneous characteristics may amplify or mitigate the direct effects of the crisis and/or determine the resilience of economies to exogenous events. At the firm level, business dynamics, financial solidity, innovation, and digital technology, among others, are all factors that can help economies be resilient to Covid-19 shock (OECD, 2021). On the contrary, pre-crisis structural weakness in these fields may have undermined firms’ ability to resist the crisis.

Considering business dynamics (in terms of firm entry, growth, and survival), the pre-crisis period has been characterized by an increase in the productivity gap between leaders and laggards, declining entry rates, job reallocation, and increasing industry concentration (Bajgar et al., 2019). These trends may be grounded in a lack of capabilities and incentives for younger and smaller firms to innovate and adopt new technologies (Calvino et al., 2020). Furthermore, pre-crisis heterogeneity in firm size and age is likely to affect the vulnerability to the financial shock caused by the crisis. Indeed, smaller and younger firms are often more financially constrained and are not usually equipped with financial cushions to allow them to survive a prolonged period of reduced activity or revenues (OECD, 2020; Bartik et al., 2020; WTO, 2021). This suggests that these firms, which under normal circumstances are an important source of innovation, employment, and productivity growth (Calvino et al., 2015), are particularly sensitive to economic shocks (Adelino et al., 2014).

Considering financial solidity, high levels of corporate debt, particularly corporate bonds, emerged in the pre-Covid-19 period (Celik et al., 2019). This increase in debt amplified financial pressures during the pandemic outbreak (Aramonte and Avalos, 2020), with highly indebted firms predicted to suffer from stronger impacts on leverage ratios and future investment (Demmou et al., 2021). High pre-crisis corporate debt could therefore be considered an aggravating factor for the risk of debt overhang. Furthermore, micro-, small- and medium-sized enterprises have suffered more than larger firms from the effects of the pandemic, owing to their limited access to finance (WTO, 2021).

Digital technologies have been a key element of resilience during the Covid-19 crisis. High-capacity communications infrastructure (e.g. a high-speed broadband connection), digital skills, and data security are all important factors enabling the use of such technologies. Countries, industries, and firms that were more involved in using these technologies before the pandemic were more likely to be resilient during the crisis. On the one hand, pre-existing divergences among firms in the adoption of digital technologies impacted their resilience. On the other hand, these divergences may have been exacerbated by the crisis: not all firms develop, adopt or use digital technologies in the same way, nor do they equally benefit from the digital transformation (Andrews et al., 2016; Gal et al., 2019). In particular, young, small, and less productive firms face major difficulties in adopting and using digital technologies; this can be mainly due to the rising importance of complementary intangible assets (e.g. skills, internal and external organization) that entail economies of scale and network effects (Corrado et al., 2021).

As for the second strand of literature, the Covid-19 pandemic could be considered a sort of “natural disaster” episode, much more so than the 2007–08 financial crisis was. This group of works has mainly analyzed the disruption of supply chains because of natural events. In this respect, the analogy between the effects of a natural disaster and those of the Covid-19 outbreak is evident: the interruption of supply chains represents a peculiar consequence of the pandemic. Trade-driven interdependence – especially the rise of global value chains – can increase firms’ exposure to sudden cut-offs in the supply or demand of inputs or outputs. It follows that even relatively small shocks to firms that are relevant in terms of linkages with other firms can temporarily block or disrupt highly interconnected networks, especially “just-in-time”
production and distribution. In this vein, the 2011 Tōhoku earthquake in Japan is estimated to have reduced the growth rate of firms with disaster-hit suppliers by 3.6 percentage points, and the firm growth rate of firms with disaster-hit customers by 2.9 percentage points (Carvalho et al., 2021; Tokui et al., 2017; Boehm et al., 2019).

To sum up, firm size, internationalization, productivity, digitalization, investments in advanced technology, and human resources emerge as potentially relevant factors in determining the resilience and reaction capacity of the business system to an exogenous crisis. The taxonomy proposed in this paper profiles Italian firms according to these aspects, controlling for the main specific consequences of the pandemic, such as interruptions in supply chains, reduced demand, and liquidity crisis.

The rest of the paper is organized as follows: Section 2 illustrates the main results of the Covid-19 survey carried out by Istat in November 2020; Section 3 describes data; Section 4 presents the empirical strategy, with an illustration of the ROC methodology from which we derive our taxonomy of economic solidity; Section 5 shows and comments on the results; Section 6 reports some robustness checks; Section 7 provides conclusions and policy recommendations.

2. The Italian business system facing the Covid-19 crisis: results from an ad hoc survey

The economic crisis resulting from the Covid-19 pandemic had deep and heterogeneous effects on Italian firms and industries. Lockdowns, a drastic reduction in demand, interruption or slowdown of value chains, and the lack of liquidity all put firms' survival at risk. In such circumstances, the effects of the crisis must be analyzed from a granular perspective, both to identify the factors of firms' resilience or vulnerability, and to study how firms reacted to the consequences of the shock.

The crisis hit Italian firms extensively and severely: according to the results of the survey on “Situation and prospects of companies in the Covid-19 emergency” carried out by Istat (2020), over two-thirds of companies with at least three employees suffered a reduction in turnover. For almost 60% of firms, the decrease in turnover was higher than 10%, and about 62% of firms expected revenues to decrease in the first six months of 2021. Less than one out of five firms (about 18%) reported no consequences or even benefited from the crisis.

Such a widespread fall in activity hindered large portions of the Italian business system: in May 2020 about 38% of companies stood at risk of closing down, and in November, 32.3% still reported the presence of economic and organizational factors capable of jeopardizing their survival. Furthermore, at that time the expectations for 2021 were quite gloomy: less than one out of five firms expected to expand its activity or maintain it in the first half of 2021.

The fall in domestic and (to a much lesser extent) foreign demand, as well as the lack of liquidity, were reported in the survey as the main effects of the sudden recession: 38.3% of firms pointed out the decrease in domestic demand as being among the major constraints on the possibility of recovery during the first half of 2021; 15.8% of firms reported problems with foreign demand; 34.1% expected risks of illiquidity, to be dealt with through a change in the structure of the sources of financing, mainly more bank credit.

Overall, the pandemic crisis had an evident size-related dimension (Fig. 1): in all macro-sectors, the proportion of firms with a sharp decline in turnover (over 10%), as well as that of firms at risk, tends to decrease as firm size increases. On average, more than 34% of “micro-firms” (i.e. 3–9 workers) reported serious operational risks; this share is 26.8% in the case of small firms (10–49 workers) and drops to between 10 and 15% for medium and large firms (50 workers and more), reaching a minimum for largest (250+ workers) industrial companies (less than 8%).

Reductions in turnover of more than 10%, although widespread in all macro-sectors, characterized to a greater extent industry and other services, but the impact was much deeper in the latter, where the share of units at risk was the highest among all class sizes. The harsher conditions, as expected, prevailed in industries most severely affected by lockdowns (Fig. 2): the proportion of firms reporting risks of closure was notably high in travel agencies (over 73%), art and entertainment (over 60%), non-residential social assistance (about 60%), air transport (59%), restaurants (about 55%). Within the manufacturing sector, however, the difficulties of the fashion supply chain stood out: clothing (over 50%), leather (about 44%), and textile (about 35%).

3. The dataset

This work is based on a dataset integrating several administrative and survey-based sources. The main source is the aforementioned Covid-19 survey, whose results were released by Istat in November 2020. This survey is a census for firms with at least 20 workers and a sample for those with 3–19 workers. From this database, we draw information on risk perception and other Covid-related difficulties encountered by firms.

Structural information on the Italian business system is drawn from the “Frame-Sbs” register. Released annually by Istat since 2011, it provides information on the structure (e.g. number of employees, business sector, location, age, legal form) and the main economic variables (e.g. value of production, turnover, value added, labor cost) for the whole population of about 4.4 million of Italian firms (2018).

Furthermore, the following firm-level sources are used:

• Racli Register, reporting information on firm employment composition (in terms of contract typology and education), wages, and labor costs for the single job position. From this archive, we draw information on employment composition and wages of the firms’ workforce (2018);
Fig. 1. Firms with turnover reductions >10% and firms at risk, by macro-sector and size class. Firms with no less than 3 workers – November 2020 (%). Source: Istat (2021).

Fig. 2. Firms at risk, by sector. Firms with no less than 3 workers – November 2020 (%). (a).
(a) 10 = Food; 11 = Beverage; 13 = Textiles; 14 = Wearing apparel; 15 = Leather; 16 = Wood; 17 = Paper; 18 = Print; 20 = Chemicals; 21 = Pharmaceutics; 22 = Rubber and plastic; 23 = Non-metallic products; 24 = Basic metals; 25 = Metal products; 26 = Electronics; 27 = Electrical equipment; 28 = Machinery; 29 = Motor vehicles; 30 = Other transport equipment; 31 = Furniture; 32 = other manufacturing; 33 = Repair; 45 = Motor vehicles trade; 46 = Wholesale trade; 47 = Retail trade; 49 = Land transport; 50 = Water transport; 51 = Air transport; 52 = Warehousing; 53 = Postal/courier services; 55 = Accommodation; 56 = Food and Beverage activities; 58 = Publishing; 59 = Video, TV, Sound and music; 60 = Broadcasting; 61 = Telecommunication; 62 = Computer programs and consulting; 63 = Information services; 68 = Real estate; 69 = Legal and accounting act.; 70 = management consultancy; 71 = Architect. And engineering act.; 72 = R&D; 73 = Advertising and market research; 74 = Other professional act.; 75 = Veterinary; 77 = Rental and Leasing; 78 = Employment activities; 79 = Travel agency/tour operator; 80 = Security and investigation; 81 = Building and landscape activities; 82 = Other business services; 85 = Education; 86 = Human health; 87 = Residential care; 88 = Social work without accommodation; 90 = Creative, arts, entertainment; 91 = Libraries, museums and other culture; 92 = Gambling and betting; 93 = Sport and recreation; 95 = Computer repair; 96 = Other personal services.
Source: Istat (2021).
Table 1
The dataset: descriptive statistics. Firms with no less than 3 workers in 2018.
Source: Authors’ calculation on Istat data.

|               | Firms Turn-over | Value added | Workers |
|---------------|----------------|-------------|---------|
|               | Units          | Min euros   | Percentage | Units          | Min euros   | Percentage | Units          | Percentage |
| **Sample**    |                |             |           |                |             |           |                |            |
| Industry      | 13740          | 489390      | 53.1      | 103085         | 47.7        | 1078744    | 38.4        |
| Construction  | 3529           | 18860       | 2.0       | 5397           | 2.5         | 89131      | 3.2         |
| Market services | 19850     | 396897      | 43.1      | 100791         | 46.6        | 1522503    | 54.2        |
| Personal services | 3125    | 16162       | 1.8       | 6900           | 3.2         | 117623     | 4.2         |
| Total         | 40244          | 921309      | 100.0     | 216173         | 100.0       | 2808002    | 100.0       |

|               | Population     |             |           |                |             |           |                |            |
| Industry      | 192723         | 1204276     | 39.3      | 281654         | 38.2        | 3741755    | 29.9        |
| Construction  | 109718         | 135376      | 4.4       | 43773          | 5.9         | 874339     | 7.0         |
| Market services | 621697    | 1638705     | 53.5      | 382889         | 51.9        | 7148718    | 57.2        |
| Personal services | 94087    | 85134       | 2.8       | 29606          | 4.0         | 742383     | 5.9         |
| Total         | 1018225        | 3063490     | 100.0     | 737921         | 100.0       | 12507194   | 100.0       |

- Asia-groups register, which provides information on firm membership and positioning within domestic and multinational groups (2018);
- Multi-purpose survey linked to the first Istat permanent Business Census Plan (MPS survey). The sample includes approximately 280,000 firms employing 3 or more workers. From this source, data on the relational and strategic profiles of the business units are extracted, as well as information on investments in innovation and digitalization (2018).
Combining these data sources, we obtain a final dataset of 40,244 firms (see Table 1), representative of the population of over 1 million firms with 3 or more workers operating in Italy in 2018.

4. Empirical strategy

This section describes the methodology used to define the taxonomy of firms’ economic solidity. In particular, Section 4.1 illustrates the ROC analysis as a classifying method. Section 4.2 presents the strategy that grounds the selection and aggregation of the relevant characteristics of Italian firms in determining their solidity. Starting from the definition of the different cut-offs obtained by applying the ROC analysis, Section 4.3 shows how the taxonomy is derived.

4.1. ROC analysis

The Receiver Operating Characteristics (ROC) analysis allows us to identify a cut-off along the value of an independent variable (classifier) in a logit model, to efficiently cluster observations with respect to a binomial status.

The ROC analysis can be traced back to classification problems in which, according to Fawcett (2005), classifiers (the relevant characteristics chosen to explain a given status of observations) can give the four possible outcomes shown in the “confusion matrix” reported in Fig. 3:

- **True Positives (TP):** positive observations are correctly classified as positive by the classifier;
- **False Negatives (FN):** positive observations are erroneously classified as negative by the classifier;
- **False Positives (FP):** negative observations are erroneously classified as positive by the classifier;
- **True Negatives (TN):** negative observations are correctly classified as negative by the classifier.

The efficiency of the classifier can be measured by using two metrics: **Sensitivity** measures the ability of the classifier to detect true positives, i.e. $TP/(TP + FN)$; **Specificity** measures the ability of the classifier to detect true negatives, i.e. $TN/(TN + FP)$, where it is usually considered in its reciprocal expression $(1-Specificity)$, which measures the correct detection of false positives.

Considering a logit model that has a binomial dependent variable (reflecting a given status) and a classifier as an explanatory variable, the distribution of probabilities resulting from the logit estimates can be displayed in the space of **Sensitivity** and **1-Specificity** by the ROC curve in Fig. 4. In other terms, once a classifier is applied, the ROC curve displays the position of each observation in the space of Sensitivity and 1-Specificity, showing the trade-off between the probability of detecting true and false positives across all possible cut-offs: it defines a map of all possible trade-offs in classifying observations (Kumar and Indrayan, 2011).

The area under the ROC curve (AUC, the sum of the gray and white portions) provides a measure of the extent to which the classifier allows us to define a more efficient classification than that originating from a purely random selection (the 45° line).\(^1\)

\(^1\) In this vein, the AUC criterion is largely used to measure the goodness of fit of logit models, and to define the relative relevance of a set of variables in determining the overall logistic distribution of probability.
To single out, along the ROC curve, the observation that most efficiently discriminates between positives and negatives (Cut), the following equation needs to be maximized:

$$\text{Cut} = h \times \text{sensitivity} - (1 - h) \times (1 - \text{specificity})$$ (1)

where $h$ and $(1 - h)$ represent the relative weights to manage the trade-off between true and false positives.

Given a value of $h$, Eq. (1) identifies the cut-off observation and, consequently, the relative value of the classifier that discriminates between two estimated classes of observations. This generates a “Manichean classification” (i.e. the positive and the negative status), according to whether the value of the classifier is over or under the threshold.

In this context, setting $h = 0.5$, a “neutral” selection is obtained and (1) corresponds to Youden’s $J$ index. Setting $h < 0.5$, i.e. finding true positives is less relevant than avoiding false positives, would correspond to a “conservative” selection, which assigns positive classifications only in the presence of strong evidence. Conversely, setting $h > 0.5$, i.e. finding true positives is more relevant than avoiding false positives, would correspond to a “liberal” selection, which assigns positive classification even in the presence of weak evidence.

In principle, for each value of $h$ from 0 to 1, starting from the same ROC curve (defined by the logit estimate), different cut-offs (and different “Manichean” classifications) may be defined. In particular, moving from a “neutral”

\footnote{For an extended treatment of the Youden’s $J$ index see Costa et al. (2019).}
As already mentioned in Section 1, we need to represent a heterogeneous, multifaceted phenomenon and, at the same time, provide a synthetic representation of it. To do so, it is possible to take advantage of the fact that different bipartitions may interact to generate more complex classifications. This is important to our purposes because it permits us to refine the classification of firms, to better grasp the heterogeneity of the solidity of Italian firms in the aftermath of the Covid-19 crisis. For this reason, in this work, we use a set of three overlapping Manichean classifications (originating from three different cut-offs) to generate a 4-class taxonomy, as shown in Fig. 5. In particular, the four classes stem from a comparison of the outcomes of the three Manichean classifications (for \( h = 0.5, h > 0.5 \) and \( h < 0.5 \)): class 1 includes firms that, according to the classifier, obtain value 0 in all Manichean bipartitions (0, 0, 0); class 2 includes firms with outcome (1, 0, 0); class 3 includes firms with outcome (1, 1, 0); class 4 includes firms with outcome (1, 1, 1).

### 4.2. The definition of the status of solidity and the classifier

In our case, the binomial status is represented by the absence (presence) of operational risk of Italian firms facing the Covid-19 pandemic crisis, as a proxy of solidity (fragility). In turn, the classifier is a combination of five relevant “pillars” of firm solidity: economic size, performance, internal organization, external organization, digitalization, and innovation. Recent literature (see Section 1) has highlighted the relevance of these factors in determining firm capability to cope with exogenous crises.

The status of the operational risk of Italian firms is gathered from the Covid-19 Survey (see Section 2). In this context, business units were asked to indicate whether they deemed their survival would be at risk in the next six months. The choice of using a survey-based proxy for solidity instead, for instance, of using administrative measures such as those based on firms’ balance sheets, is due to the need to maximize coverage of the Italian business system. The use of financial statements would limit our analysis only to corporations, which in 2018 accounted for less than 25% of total Italian enterprises. In particular, this would rule out from the analysis a large part of small and medium firms, which represent the largest part of the Italian business system (unincorporated firms with less than 50 employees account for 81.9% of total firms, 24.5% of total value added, 41.3% of total employment) and have been particularly hit by the pandemic. Their exclusion would therefore lead to an overestimation of the solidity of the Italian business system.

The classifier is an aggregation of composite indicators referring to the five pillars of firm economic solidity. Starting from its basic components, each pillar is built by firstly linearizing binomial and categorical variables and, then, aggregating all components through factor analysis. Each composite indicator is defined based on the first factor. Table 2 reports, for each indicator, the components taken into consideration (including the type of variable and how it is calculated).

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3 In building up Manichean taxonomies, the use of “neutral” strategy is somehow “natural” when there is not a strong prior about the weight of errors. However, when this prior exists (this particularly holds in medicine, where the cost of badly classifying healthy and diseased persons could be very high), \( h \) can be efficiently set to lower or higher values than 0.5.

4 Descriptive statistics for elementary components for each pillar are provided in Appendix A.
Table 2
Pillars of economic solidity and their elementary components.

| Composite indicators | Elementary components | Type | Notes |
|----------------------|-----------------------|------|-------|
| Economic size        | Number of workers     | Continuous | Positions |
|                      | Turn-over             | Continuous | Level |
|                      | Age                   | Continuous | Months |
|                      | Capital intensity     | Continuous | Depreciation of fixed asset per worker |
| Performance          | Productivity          | Continuous | Value added per worker |
|                      | Profitability         | Continuous | Gross operating surplus/Value added |
|                      | Cost competitiveness  | Continuous | Per worker value added/Average compensation of employees |
| Internal organization| Presence of external management | Binomial | Management other than the owner |
|                      | Belonging to groups   | Categorical | No participation to groups, belonging to domestic groups or belonging to multinational groups |
|                      | Share of high skilled workers | Continuous | Workers with tertiary education/Total workers |
|                      | Share of workers with permanent position | Continuous | Workers with permanent position/Total workers |
|                      | Average compensation of employees | Continuous | Per capita compensation of employees |
|                      | Presence of investments in human resources | Continuous | Presence of investments in staff training |
| External organization| Presence of non-arms length agreements with other firms | Binomial | Presence of collaboration agreements with other firms |
|                      | Number and typology of non arms-length agreements with other firms | Categorical | Weighted measure of the number and complexity of relationships |
|                      | Capability of activation of the productive system | Continuous | Weighted average of the activation coefficient of the firm and characteristics of sectoral supply-chain |
|                      | Internationalization  | Binomial | Presence of exports and/or imports |
| Digitalization and innovation | Presence of investments in innovation | Binomial | The firm has positive investments in innovation (product and/or process) |
|                      | Technology adoption   | Continuous | Sum of expenses in licences and royalties, PC and software, R&D |
|                      | Presence of investments in digitalization | Binomial | The firm has positive investments in digitalization |

Our classifier is obtained by the following linear combination of the composite indicators:

\[ C_i = \alpha_1 ES_i + \alpha_2 P_i + \alpha_3 IO_i + \alpha_4 EO_i + \alpha_5 ID_i \]  \hspace{1cm} (2)

where, for the ith firm, \( ES_i \) is the economic size, \( P \) is the performance, \( IO_i \) is the internal organization, \( EO_i \) is the external organization, \( ID_i \) is the innovation and digitalization.

Weights in Eq. (2) are the coefficients of the following logit model:

\[ \text{Prob (Solidity}_{i} = 1 | ES_i, P_i, IO_i, EO_i, ID_i, nace_i, geo_i, liq_i, diff_i, legal_i) = \frac{\Lambda(\alpha_1 ES_i + \alpha_2 P_i + \alpha_3 IO_i + \alpha_4 EO_i + \alpha_5 ID_i + \alpha_6 nace_i + \alpha_7 geo_i + \alpha_8 liq_i + \alpha_9 diff_i + \alpha_{10} legal_i)}{1 + \Lambda(\alpha_1 ES_i + \alpha_2 P_i + \alpha_3 IO_i + \alpha_4 EO_i + \alpha_5 ID_i + \alpha_6 nace_i + \alpha_7 geo_i + \alpha_8 liq_i + \alpha_9 diff_i + \alpha_{10} legal_i)} \]  \hspace{1cm} (3)

where \( \Lambda \) is the logistic distribution function and, for the ith firm, \( nace, geo, liq, diff \) are controls for industry (Nace rev.2 at 2-digit level), territory (NUTS2 level), presence of liquidity constrains, demand and supply side difficulties related to Covid-19 pandemic. In particular, \( liq \) is a dummy variable (from the Covid survey) assuming value 1 if the firm signaled severe liquidity shortage because of the pandemic outbreak, 0 otherwise. \( diff \) is a categorical variable (from the Covid survey) measuring the intensity of problems occurring on demand and/or supply side aspects. Finally, \( legal \) is a categorical variable accounting for three types of legal forms (unincorporated units, corporations, other forms) to control for possible ownership-driven biases in the perception of risk, more likely to be present in smaller firms. \( nace \) is a dummy variable indicating whether the firm is in a sector identified by the Italian Classification of Economic Activities, rev. 2.

Table 3 shows some tests about the goodness of fit of the logit model, in particular the share of concordant cases and the AUC (both over 77%).

In other words, the model shows a high capability of estimating the conditions of firms facing the crisis. Moreover, this procedure allows us to obtain a classifier where the effects (the weights) of the five pillars are “net” of geographic, sectoral and pandemic-related effects. This permits us to generalize the analysis of the Italian business system solidity beyond Covid-specific effects.

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5 In particular, demand side aspects include: reduction in attractiveness of goods and services, reduction in demand determined by anti-contagion measures (administrative restrictions, social distancing); reduction in domestic demand; reduction in foreign demand; increase in transport and logistic costs. Supply side aspects include: reduction or interruption of the supply of raw materials and/or intermediate inputs; price increase of raw materials and/or intermediate inputs; increase in transport and logistic costs. The variable takes value 1 if the firm signaled at least one of demand or supply side issues; it takes value 2 if the firm signaled difficulties on both demand and supply side aspects; it takes value 0 if no problems occurred.
### 4.3. Definition of cut-offs and four-class taxonomy

Once the firms’ status (i.e. the economic solidity) and the classifier (i.e. the indicator obtained in Eq. (2)) are defined, the ROC analysis can be carried out starting from the following logit estimate:

\[
\text{Prob} (\text{Solidity} = 1 | E_S, P_i, I_O, E_O, I_D) = \frac{e^{(\hat{\alpha}_1 E_S + \hat{\alpha}_2 P_i + \hat{\alpha}_3 I_O + \hat{\alpha}_4 E_O + \hat{\alpha}_5 I_D)}}{1 + e^{(\hat{\alpha}_1 E_S + \hat{\alpha}_2 P_i + \hat{\alpha}_3 I_O + \hat{\alpha}_4 E_O + \hat{\alpha}_5 I_D)}} = A \left( \hat{\xi} \right)
\]  

(4)

where \( \hat{\alpha}_k \) are the weights estimated using the model in Eq. (3), net of the effect of the control variables. The resulting values of Eq. (4) allow for obtaining a ROC curve, from which we derive our four-class taxonomy. To do so, we follow a three-step procedure.

The first step is to set \( h = 0.5 \) in order to define the first “neutral” cut-off that classifies firms into “Solid” (i.e. classified as 1, with a value of the classifier over the threshold) and “Fragile” (i.e. classified as 0, with a value of the classifier under the threshold).

The second and third steps define the two further cut-offs needed to complete our taxonomy. In particular, in the second step, we run one hundred ROC estimates (corresponding to different values of \( h \)) to determine which values of \( h < 0.5 \) and \( h > 0.5 \) should be set up as the remaining cut-offs. Fig. 6 shows the results of all the Manichean classifications (the number of Solids and Fragiles) generated by the ROC corresponding to each value of \( h \).

In the third step, we move from a “neutral” selection (\( h = 0.5 \)), considering both a “conservative” (\( h < 0.5 \)) and a “liberal” selection (\( h > 0.5 \)). In particular, we identify the cut-offs (\( h_- \) and \( h_+ \)) corresponding to the higher jumps in the firm’s distributions along sliding \( h \). To determine those values we consider the absolute changes in the distribution:

\[
\begin{align*}
\text{h}_- &= \max (n_h - n_{h-0.01}), \quad 0 \leq h \leq 0.5 \\
\text{h}_+ &= \max (n_h - n_{h+0.01}), \quad 0.5 \leq h \leq 1
\end{align*}
\]

(5a)

(5b)

where \( n_h \) represents the number of firms which lay under or over the threshold for each value of \( h \). This procedure selected \( h_- = 0.48 \) and \( h_+ = 0.60 \) (see also Fig. 7).

These latter three values of \( h (h_-, h_+ \) and \( h_{\text{res}}) \) are used as cut-offs to build up our final taxonomy. Classes are defined by the intersection of the three statuses (i.e. over/under the threshold) as follows:

- **Solid** firms those lying over the threshold estimated in correspondence to \( h = 0.48 \);
- **Resistant** firms: those lying over the threshold for \( h = 0.5 \) and under the threshold for \( h = 0.48 \);
- **Fragile** firms: those under the threshold for \( h = 0.5 \) and over the threshold for \( h = 0.60 \);
- **At Risk** firms: those under the threshold for \( h = 0.60 \).

---

**Table 3**

Goodness of fit of the model.

| Association of predicted probabilities and observed responses | Percent concordant | Somers’ D | Gamma | Percent discordant | Tau-a | Pairs | AUC |
|---------------------------------------------------------------|-------------------|-----------|-------|--------------------|-------|-------|-----|
| 77.5                                                          | 0.554             |           |       | 22.2               | 0.555 |       |     |
| 0.3                                                           | 0.213             |           |       |                    |       |       |     |
| 310,209,060                                                   | 0.777             |           |       |                    |       |       |     |
5. The degree of solidity of the Italian business system

5.1. Solidity of the taxonomy: a description

This taxonomy helps to analyze the degree of solidity of the Italian business system against exogenous and violent shocks such as the pandemic episode of 2020–2021.

Firstly, our classification confirms that this type of crisis has a clear size-related dimension. The distribution among size classes reported in Fig. 8 shows that the impact has been much more severe for smaller firms: the micro enterprises (3–9 workers) have the largest incidence of units classified as At Risk (38.0%) and Fragile (40.5%); among the small ones (10–49 workers) these percentages are 13.0 and 30.5% respectively. On the contrary, among medium-sized and large enterprises Solid firms largely prevail (77.1% and 89.1%, respectively).
The size issue is relevant, but as it is well-known, crises like the pandemic also have a relevant sectoral dimension. In this respect, Table 4 reports the structural characteristics of each class by macro-sector. The group of Solid accounts for less than 20% of the Italian businesses system, but it represents by far the most significant share in terms of employment (54.9%) and even more in terms of value added (76.4%). In other terms, at the end of 2020 the majority of Italian employment and three-quarters of value added were still in a “solid” condition. The At-Risk units account for 32.5% of the total but they play a much less significant role in the economy (14.4% of employment and 4.1% of value added), due to their smaller size (5.5 workers on average, compared to nearly 35 for the Solid). However, 37.9% of Italian firms are classifiable as Fragile; in these units, 21.9% of total workers are employed, generating 12.6% of total value added. Finally, only 10.3% of firms are “Resistant”, accounting for 8.7% of total employment and 6.9% of value added.

These results basically reflect the context of industrial sectors: among the macro-sectors considered in Table 4, Industry contribution to the overall solidity – in terms of units, employment, value added – is the highest. On the contrary, the state of firms appears worrying in Construction and Other services, where 61.7% of firms are Fragile and 49.0% are At Risk. In these two macro-sectors, over half of workers are employed in At Risk or Fragile firms. More specifically, in all macro-sectors solid units have the highest shares in terms of value added, ranging from 47.8% in Construction to 84.1% in Industry. In terms of employment, however, Solid units represent the largest class in Industry (59.3% of firms) and in Services (both Market and Other services, 52.1% and 39.4% respectively), while in Construction and Other services more than half of workers are employed in Fragile or At Risk firms.

5.2. The role of the five pillars

To better investigate the role of profound characteristics on the probability of being At Risk, Fragile, Resistant or Solid, we report the values of the five pillars (aggregated by the composite indicators described in Section 4.2) across the macro-sectors and the classes of taxonomy in Table 5. For each pillar, the ratio between the class average and the macro-sector average is displayed. This ratio shows how the value of each indicator (pillar) differs within the classes of solidity. For example, values above (below) 1 indicate that a given class value is over (under) the average: the higher the value, the more relevant the pillar is in characterizing that class.

Overall, for each indicator, the ratio increases when moving towards higher solidity classes, implying that these latter are characterized by a higher relevance of the pillars. A soundness status (Resistant or Solid) is associated with above-average economic size, digitalization and innovation values. These elements confirm the characteristics of the Covid-19 pandemic.
Table 5
Structural characteristics of firms according to their solidity: the role of five pillars. Firms with no less than 3 workers. 
Source: Authors’ calculations on Istat data.

| Indicator                                  | Distance from the average by class (Class/Total average ratio) |
|-------------------------------------------|---------------------------------------------------------------|
|                                           | At risk | Fragile | Resistant | Solid |
| **Industry**                              |         |         |           |       |
| Economic size                             | 0.852   | 0.891   | 0.934     | 1.303 |
| Performance                               | 0.977   | 0.997   | 1.005     | 1.020 |
| Internal organization                      | 0.759   | 0.900   | 1.012     | 1.321 |
| External organization                      | 0.654   | 0.962   | 1.066     | 1.279 |
| Digitalization and innovation              | 0.159   | 0.471   | 1.143     | 2.339 |
| **Construction**                          |         |         |           |       |
| Economic size                             | 0.648   | 0.875   | 1.220     | 1.844 |
| Performance                               | 0.954   | 1.003   | 1.013     | 1.032 |
| Internal organization                      | 0.822   | 0.964   | 1.074     | 1.324 |
| External organization                      | 0.778   | 0.975   | 1.177     | 1.243 |
| Digitalization and innovation              | 0.335   | 0.652   | 2.058     | 2.626 |
| **Market services**                        |         |         |           |       |
| Economic size                             | 0.597   | 0.781   | 0.922     | 2.233 |
| Performance                               | 0.968   | 0.999   | 1.017     | 1.056 |
| Internal organization                      | 0.768   | 0.982   | 1.125     | 1.424 |
| External organization                      | 0.638   | 0.985   | 1.228     | 1.617 |
| Digitalization and innovation              | 0.338   | 0.830   | 1.442     | 2.376 |
| **Personal services**                      |         |         |           |       |
| Economic size                             | 0.769   | 0.864   | 1.077     | 1.981 |
| Performance                               | 0.894   | 1.020   | 1.108     | 1.254 |
| Internal organization                      | 0.838   | 1.015   | 1.155     | 1.424 |
| External organization                      | 0.628   | 1.116   | 1.584     | 1.774 |
| Digitalization and innovation              | 0.375   | 0.886   | 2.100     | 2.711 |
| **Total**                                 |         |         |           |       |
| Economic size                             | 0.510   | 0.840   | 1.099     | 1.567 |
| Performance                               | 0.776   | 1.016   | 1.048     | 1.069 |
| Internal organization                      | 0.640   | 1.068   | 1.128     | 1.403 |
| External organization                      | 0.598   | 1.139   | 1.173     | 1.310 |
| Digitalization and innovation              | 0.303   | 0.694   | 1.480     | 2.512 |

crisis: the hardest effects tend to be suffered by small-sized enterprises (Istat, 2021) and by firms with a very low level of digitalization (Marques-Santos et al., 2021). Even high values (i.e. over 1) of the other three indicators (performance, internal and external organization) do not guarantee a status of solidity or resistance. In addition to being larger in size (1.6 times the average of the business system) and more digitalized (2.5 times the average), Solid units are also characterized by a high degree of organizational complexity. Moreover, the firm performance indicator seems less able to determine the belonging of firms to different classes: good economic results in pre-crisis period do not represent – per se – a shelter from the crisis.

These general results, however, hide a high sectoral heterogeneity. For example, in Construction and Other services, a “sound” condition – i.e. one assuring at least a Resistant status – implies above-average levels of digitalization and economic size; as for Industry and Market services, however, being Resistant is consistent with below-average economic size, while it still requires relatively high digitalization and innovation values. On the contrary, for the other two macro-sectors (Other services and Construction), it is necessary to reach higher than average levels in all five pillars to escape from a risky condition.

Consistent with the general results, therefore, the transition from the condition of Resistant to the Solid status appears to be driven, in all sectors, by a jump in the economic size; as for the level of digitalization, this is most evident in Industry and Market services. On the one hand, in all macro-sectors, the factors discriminating between Risky and Fragile, in addition to digitalization, are mainly related to external organization; in Construction and Market services, on the other hand, the differences in the economic size values also contribute to avoiding a risky condition.

6. Robustness check

However, our taxonomy may crucially depend on the estimated coefficients in Eq. (3), which determine the classifier used in the ROC analysis and, consequently, the choice of \( h_s \) (and hence the cut-offs). It follows that, if the estimated coefficients changed, we could have a different distribution of firms into the four-class classification.
Table 6
Kendall rank correlation test results.

| Taxonomy       | Solids | Resistants | Fragiles | At risk | Total  |
|----------------|--------|------------|----------|---------|--------|
| Solids         | 14,505 | 679        | 28       | 1       | 15,213 |
| Resistants     | 861    | 3,077      | 744      | 1       | 4,683  |
| Fragiles       | 2      | 1,431      | 10,406   | 1,847   | 13,686 |
| At risk        | 0      | 0          | 311      | 6,351   | 6,662  |
| Total          | 15,368 | 5,187      | 11,489   | 8,200   | 40,244 |

**Kendall's test**

- Number of obs = 40,244
- Kendall's tau-a = 0.6412
- Kendall's tau-b = 0.9061
- Kendall's score = 5.2e+08
- SE of score = 2433536.512 (corrected for ties)

Test of Ho: taxonomy and taxonomy_lower are independent

| Taxonomy       | Solids | Resistants | Fragiles | At risk | Total  |
|----------------|--------|------------|----------|---------|--------|
| Solids         | 14,508 | 705        | 0        | 0       | 15,213 |
| Resistants     | 336    | 3,023      | 1,324    | 0       | 4,683  |
| Fragiles       | 0      | 194        | 11,383   | 2,109   | 13,686 |
| At risk        | 0      | 0          | 79       | 6,583   | 6,662  |
| Total          | 14,844 | 3,922      | 12,786   | 8,692   | 40,244 |

By applying the upper and lower values of those intervals to Eq. (2) we obtain a “confidence interval” determined by the value of the classifier. We consider the 95% confidence interval of the marginal effects of the pillars estimated in Eq. (3).

To test the robustness of the taxonomy, we assess how this latter would vary in response to a change in firm-level value of the classifier. We consider the 95% confidence interval of the marginal effects of the pillars estimated in Eq. (3).

Finally, we compare these new two taxonomies with the one estimated in Section 5 in order to assess whether their distributions are independent. To do so, we apply the Kendall rank correlation test. In this context, the benchmark is represented by the taxonomy defined at the end of Section 4, while “Taxonomy_lower” is the classification derived from \( \hat{C}_{i,1} \) and “Taxonomy_upper” is the classification derived from \( \hat{C}_{i,2} \). Table 6 shows the results of the Kendall test, which reject the null hypothesis of independence (i.e., our taxonomy seems to be robust to changes in values of the classifier) and the transition matrices between these taxonomies.

7. Conclusions and policy recommendation

In this paper, we study the “solidity” of the Italian business system, using the Covid-19 pandemic as an exogenous event to test it. To this aim, we use the ROC methodology, quite a new approach in Economics; furthermore, we use it in a new way, setting three overlapping Manichean classifications to generate a four-class taxonomy classifying Italian firms according to their degree of solidity: Solid, Resistant, Fragile, At Risk.

In this respect our taxonomy shows that, a year after the beginning of the pandemic, the Italian business system appeared fundamentally solid: even though the group of solid firms accounts for less than one fifth of Italian firms with no less than 3 workers, it includes the most relevant firms in terms of employment and value added. However, even if the business units classified as Fragile and At Risk are not so relevant in terms of value added, they account for over one third of total employment, so that a possible disappearance of this business segment might cause severe social and economic problems. Moreover, in line with the literature, the size-related effects of the crisis are confirmed by our taxonomy: among the smallest firms, the percentage of units at risk is about seven (for 10–49 workers) and twenty (for 3–9 workers) times higher than among the largest size class (250+ workers); the share of Fragile is about five and seven times higher respectively.

We also find that the solidity of Italian firms – and their ability to resist exogenous crises such as the pandemic-related one – rests on some relevant pillars, i.e. economic size (a broader notion than the mere number of workers), performance, internal organization, external organization, digitalization/innovation. Furthermore, some pillars appear more relevant than others; in particular, economic size is crucial: a pre-crisis (2018) relatively large size strongly discriminates between positive (Resistant or Solid) and negative (At Risk and Fragile) statuses. However, in industrial and market services activities, a Resistant status can be associated with below-average economic size values, while in Construction and Other...
services, an above-average economic size is sufficient for a firm to be Solid but not Resistant. At the same time, firms with a low level of digitalization and innovation appear much less solid: levels of digitalization are very different between At Risk/Fragile firms and Resistant/Solid ones. This is consistent, on the one hand, with the gap between Italian firms in advanced digitalization and, on the other hand, with the strong technological polarization that seems to characterize the Italian business system. As for the other three pillars (performance, internal and external organization), higher-than-average values do not guarantee a status of solidity or resistance. In this respect, it is noteworthy that even having achieved good economic results in the pre-pandemic period does not represent – *per se* – a shelter from the economic consequences of an exogenous crisis such as the pandemic one.

From these analyses two main elements emerge. The first is strictly related to the fact that Covid-19 forced firms to increase the incidence of digital trade and organize remote working for employees. This may have increased the relevance of digitalization in determining structural solidity. The second element is the role of economic size and digitalization in giving firms a perspective of soundness, while previous higher-than-average levels of performance, or internal and external organization, may generally be not enough for firms to be resilient or to thrive.

Some useful policy indications follow. First, faced with an event such as the one considered here, in the short term it appears essential to implement measures to help and support smaller firms because, as we have seen, even the most organized and dynamic among them tend to be fragile or at risk. Second, providing medium-long term policies aimed at stimulating firm growth is of great importance, not only to increase firms’ competitiveness, but also their structural solidity.

In order to achieve such goals, a granular representation of the business system need to be available. In this regard, as in testing the solidity of buildings in the aftermath of a seismic event, our approach appears capable of providing a map of the solidity of Italian firms, which also allows us to investigate its “profound”, long-term determinants. This map can be used to inform policies of business support and consolidation, and it would make it possible to design more precise and effective (and less expensive) policy measures.

Appendix A

Table A.1 reports the descriptive statistics of each elementary component of the five composite indicators (Pillars).

### Table A.1
The Pillars: descriptive statistics.

*Source: Authors’ elaborations on Istat data.*

| Economic size | Obs | Population | Mean | Std. Dev. | Min | Max |
|---------------|-----|------------|------|-----------|-----|-----|
| Number of workers | 40,244 | 1018225 | 12.3 | 143.7 | 2.5 | 50411.9 |
| Turn-over | 40,244 | 1018225 | 3016.5 | 72407.0 | −148879.9 | 44500000.0 |
| Age | 40,244 | 1018225 | 24.7 | 13.8 | −1.0 | 137.0 |
| Capital intensity | 40,244 | 1018225 | 0.0 | 2.5 | 0.0 | 957.7 |

| Performance | Obs | Population | Mean | Std. Dev. | Min | Max |
|--------------|-----|------------|------|-----------|-----|-----|
| Productivity (value added/workers) | 40,244 | 1018225 | 37.7 | 58.0 | −1811.1 | 12710.5 |
| Profitability | 40,244 | 1018225 | −0.3 | 49.2 | −6146.8 | 161.8 |
| Cost competitiveness | 40,244 | 1018225 | 0.0 | 0.0 | −0.1 | 0.2 |

| Internal organization | Obs | Population | Mean | Std. Dev. | Min | Max |
|-----------------------|-----|------------|------|-----------|-----|-----|
| Presence of external management | 40,244 | 1018225 | 0.0 | 0.2 | 0.0 | 1.0 |
| Belonging to groups (IT and Foreign) | 40,244 | 1018225 | 0.1 | 0.4 | 0.0 | 2.0 |
| Share of high skilled workers | 40,244 | 1018225 | 0.1 | 0.2 | 0.0 | 1.0 |
| Share of workers with permanent position | 40,244 | 1018225 | 0.8 | 0.3 | 0.0 | 1.0 |
| Average compensation of employees | 40,244 | 1018225 | 18614.7 | 9249.4 | 0.0 | 663170.7 |
| Presence of investments in human resources | 40,244 | 1018225 | 0.0 | 0.2 | 0.0 | 1.0 |

| External organization | Obs | Population | Mean | Std. Dev. | Min | Max |
|-----------------------|-----|------------|------|-----------|-----|-----|
| Presence of non-arms length agreements with other firms | 40,244 | 1018225 | 0.8 | 1.0 | 0.0 | 4.0 |
| Number and typology of non arms-length agreements with other firms | 40,244 | 1018225 | 2.5 | 1.9 | 1.0 | 30.0 |
| Capability of activation of the productive system | 40,244 | 1018225 | 0.1 | 2.1 | −0.1 | 1051.7 |
| Internationalization | 40,244 | 1018225 | 0.0 | 0.1 | 0.0 | 1.0 |

| Digitalization and innovation | Obs | Population | Mean | Std. Dev. | Min | Max |
|------------------------------|-----|------------|------|-----------|-----|-----|
| Presence of investments in innovation | 40,244 | 1018225 | 1.5 | 1.0 | 1.0 | 10.0 |
| Technology adoption | 40,244 | 1018225 | 0.0 | 0.0 | 0.0 | 0.9 |
| Presence of investments in digitalization | 40,244 | 1018225 | 0.0 | 0.2 | 0.0 | 1.0 |
Appendix B

This appendix reports the results of the taxonomy by industry (2-digit NACE rev.2). In particular, Table B.1 displays, for each class of economic solidity, the distribution of the whole universe of Italian firms with no less than 3 workers (determined by using survey weights).

Table B.1
Distribution of firms by sector (2-digit NACE rev.2) and degree of solidity. Firms with no less than 3 workers.
Source: Authors’ elaborations on Istat data.

| Industry                                      | At risk | Fragile | Resistant | Solid | Total |
|-----------------------------------------------|---------|---------|-----------|-------|-------|
| Mining and quarrying                          | 16.6    | 30.6    | 41.5      | 11.3  | 100.0 |
| Food                                          | 52.4    | 26.2    | 8.4       | 12.9  | 100.0 |
| Beverage                                      | 16.2    | 27.3    | 14.5      | 42.0  | 100.0 |
| Textile                                       | 20.6    | 44.8    | 11.4      | 23.2  | 100.0 |
| Wearing apparels                              | 35.7    | 38.8    | 8.4       | 17.1  | 100.0 |
| Leather                                       | 24.8    | 40.2    | 11.0      | 24.2  | 100.0 |
| Wood                                          | 19.5    | 61.1    | 8.8       | 10.5  | 100.0 |
| Paper                                         | 8.2     | 44.9    | 13.6      | 33.3  | 100.0 |
| Printing                                      | 13.6    | 49.9    | 14.8      | 21.7  | 100.0 |
| Coke and refined petroleum products           | 2.8     | 19.8    | 14.9      | 62.6  | 100.0 |
| Chemical                                      | 1.8     | 25.8    | 10.8      | 61.6  | 100.0 |
| Pharmaceutics                                 | 0.0     | 1.4     | 6.8       | 91.9  | 100.0 |
| Rubber and plastic                           | 5.9     | 40.7    | 15.3      | 38.2  | 100.0 |
| Non metallic minerals                         | 15.5    | 50.4    | 9.6       | 24.6  | 100.0 |
| Metals                                        | 4.5     | 28.6    | 13.8      | 53.1  | 100.0 |
| Metal products                                | 13.3    | 43.7    | 19.2      | 23.8  | 100.0 |
| Electronics                                   | 4.8     | 36.2    | 10.9      | 48.1  | 100.0 |
| Electric apparel                              | 6.3     | 39.6    | 13.7      | 40.4  | 100.0 |
| Machinery                                     | 2.3     | 28.6    | 17.9      | 51.1  | 100.0 |
| Motor vehicle                                 | 6.8     | 28.5    | 21.7      | 43.0  | 100.0 |
| Other transport equipment                     | 6.4     | 42.5    | 13.3      | 37.8  | 100.0 |
| Furniture                                     | 15.1    | 58.8    | 10.8      | 15.3  | 100.0 |
| Other manufacturing                           | 19.7    | 51.3    | 11.7      | 17.4  | 100.0 |
| Installation and repair                       | 10.0    | 48.4    | 14.1      | 27.5  | 100.0 |
| Energy                                        | 3.2     | 5.8     | 7.7       | 83.3  | 100.0 |
| Water                                         | 10.7    | 15.1    | 5.3       | 68.9  | 100.0 |
| Sewerage                                      | 9.3     | 38.2    | 20.6      | 31.9  | 100.0 |
| Waste                                         | 9.2     | 29.7    | 9.9       | 51.2  | 100.0 |
| Remediation and other waste                   | 13.9    | 35.9    | 14.4      | 35.7  | 100.0 |
| Building construction                         | 15.8    | 56.8    | 10.5      | 16.9  | 100.0 |
| Civil engineering                             | 6.6     | 44.2    | 16.2      | 33.1  | 100.0 |
| Specialized construction                      | 15.5    | 64.3    | 9.7       | 10.5  | 100.0 |
| Motor vehicle trade                           | 29.9    | 53.6    | 6.5       | 10.0  | 100.0 |
| Wholesale trade                               | 13.1    | 42.1    | 13.6      | 31.2  | 100.0 |
| Retail trade                                  | 37.4    | 40.6    | 8.4       | 13.7  | 100.0 |
| Land transport                                | 19.2    | 55.1    | 11.0      | 14.7  | 100.0 |
| Water transport                               | 10.6    | 18.0    | 9.9       | 61.5  | 100.0 |
| Air transport                                 | 8.9     | 5.8     | 0.0       | 85.4  | 100.0 |
| Warehousing                                   | 12.2    | 27.5    | 15.6      | 44.6  | 100.0 |
| Postal and courier activities                 | 23.5    | 41.6    | 3.2       | 31.7  | 100.0 |
| Accommodation                                 | 53.0    | 25.4    | 9.0       | 12.6  | 100.0 |
| Food and beverage services                    | 80.2    | 15.1    | 2.6       | 2.0   | 100.0 |
| Publishing                                    | 4.1     | 28.1    | 18.2      | 49.6  | 100.0 |
| Video and television                          | 8.3     | 23.7    | 9.8       | 58.2  | 100.0 |
| Programming and broadcasting                  | 25.8    | 31.2    | 13.5      | 29.4  | 100.0 |
| Telecommunications                            | 6.7     | 27.8    | 8.3       | 57.3  | 100.0 |
| Computer programming                          | 1.7     | 17.0    | 13.7      | 67.6  | 100.0 |
| Information services                          | 8.6     | 56.1    | 15.6      | 19.7  | 100.0 |
| Financial auxiliaries                         | 7.4     | 46.6    | 19.6      | 26.4  | 100.0 |
| Real estate                                   | 18.8    | 33.4    | 18.0      | 29.8  | 100.0 |
| Legal and accounting                          | 5.7     | 45.3    | 22.4      | 26.6  | 100.0 |
| Management consultancy                        | 5.9     | 16.8    | 8.3       | 69.0  | 100.0 |
| Architecture and engineering                  | 4.0     | 29.0    | 22.1      | 44.9  | 100.0 |
| Research and development                      | 0.5     | 11.4    | 5.2       | 82.8  | 100.0 |
| Advertising and market research                | 5.5     | 32.7    | 16.7      | 45.1  | 100.0 |
| Other professional services                   | 10.1    | 31.9    | 16.3      | 41.8  | 100.0 |
| Rental and leasing                            | 16.7    | 36.0    | 12.9      | 34.4  | 100.0 |
| Employment activities                         | 5.6     | 5.8     | 7.6       | 81.0  | 100.0 |
| Travel agencies and tour operator             | 18.2    | 41.0    | 14.8      | 26.0  | 100.0 |

(continued on next page)
Table B.1 (continued).

| Industry | At risk | Fragile | Resistant | Solid | Total |
|----------|---------|---------|-----------|-------|-------|
| Security and investigation | 27.9 | 33.8 | 16.7 | 21.5 | 100.0 |
| Building and landscape services | 62.9 | 27.8 | 4.2 | 5.1 | 100.0 |
| Other business services | 17.1 | 34.1 | 10.8 | 38.0 | 100.0 |
| Education | 29.5 | 29.2 | 10.1 | 31.2 | 100.0 |
| Human healthcare | 18.2 | 39.3 | 13.4 | 29.1 | 100.0 |
| Residential care | 41.3 | 29.9 | 8.5 | 20.4 | 100.0 |
| Non-residential care | 45.9 | 39.3 | 5.2 | 9.6 | 100.0 |
| Creative activities, art and entertainment | 19.0 | 49.3 | 13.6 | 18.0 | 100.0 |
| Libraries and museums | 32.4 | 45.0 | 7.5 | 15.2 | 100.0 |
| Gambling and betting | 31.7 | 44.9 | 8.8 | 14.5 | 100.0 |
| Sport and amusement | 64.0 | 21.6 | 4.5 | 9.9 | 100.0 |
| Computer repair | 31.6 | 51.0 | 6.3 | 11.1 | 100.0 |
| Other personal services | 73.5 | 18.3 | 3.9 | 4.2 | 100.0 |
| Total | 32.5 | 37.9 | 10.3 | 19.4 | 100.0 |

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