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Firm characteristics and survival in times of COVID 19: First evidence from Kernel Regularized Least Squares regressions*

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Abstract

This paper uses firm level data from the World Bank Enterprise surveys conducted in 2019 and from the COVID-19 follow-up surveys conducted in 2020 in eight European countries to investigate the link between firm characteristics before the pandemic and firm survival until 2020. For the first time the marginal effects of firm characteristics are computed by a new machine-learning estimator, Kernel Regularized Least Squares (KRLS), which makes no restrictive assumptions regarding the functional form of the empirical model used. A comparison with results from a standard parametric approach, Probit regression, reveals important differences.

JEL classification: D22, F14, L20, L25, L29

Keywords: Firm survival, COVID-19, World Bank Enterprise Survey, kernel regularized least squares (KRLS)

* The data from the World Bank Enterprise surveys used in this paper are available after registration from the website https://www.enterprisesurveys.org/portal/login.aspx . Stata code used to generate the empirical results reported in this note is available from the author.

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1 Motivation

When the coronavirus and COVID-19 reached Europe in the first quarter of 2020 firms were hit by negative demand shocks due to quarantine and lockdown measures. Furthermore, supply chains were damaged and this led to negative supply shocks. These shocks had a negative impact on many dimensions of firm performance. Waldkirch (2021) reports evidence on the impact of the COVID-19 pandemic on firms around the world based on the so-called COVID-19 follow-up surveys to the World Bank's Enterprise Surveys conducted in 2020. Empirical studies are surveyed in Belitski et al. (2022) and Muzi et al. (2023).

Some firms were hit so hard by these negative exogenous shocks that they decided to close down permanently. An important question that is investigated in a number of papers is which characteristics of firms help many of them to survive the pandemic. Empirical studies that use the World Bank's Enterprise surveys to study firm exit during the COVI-19 pandemic include Wagner (2021) and Cariolle and Léon (2022) with a focus on the role of having a website; Khan et al. (2022) who study the role of innovations; Muzi et al (2023) who look at productivity; Grover and Karplus (2021) with a focus on management pratices; Wagner (2022) who looks at the role of the gender of firm owners; and Wagner (2024) who investigates the link between export activity and firm exit.

This paper contributes to the literature by using firm level data from the World Bank Enterprise surveys conducted in 2019 and from the COVID-19 follow-up surveys conducted in 2020 in eight European countries to investigate the link between various firm characteristics before the pandemic and firm survival until 2020. In doing so it uses a "natural experiment" – an unanticipated external negative shock – to look at these effects on firm survival.

Furthermore, in earlier studies firm characteristics enter the empirical models for firm survival usually in linear form. If non-linear relationships do matter and if they are ignored in the specification of the empirical model this leads to biased results. Researchers, however, can never be sure that all possible non-linear relationships are taken care of in their chosen specifications, because the number of polynomials and interaction terms that might be relevant grows exponentially when the number of firm characteristics included in the empirical models for firm survival increases. In this paper for the first time the marginal effects of firm characteristics are computed by a new machine-learning estimator, Kernel Regularized Least Squares (KRLS), introduced in Hainmueller and Hazlett (2014) and Ferwerda, Hainmueller and Hazlett (2017), and outlined in section 3.2 below (see also Wagner (2025)). KRLS uses a machine learning approach to learn the functional form from the data. In doing so, it protects against misspecification that leads to biased estimates.

To anticipate the most important result of this note it turns out that due to the misspecification of the functional form used in the standard empirical model estimated by Probit the application of KRLS regression leads to different conclusions with regard to some firm characteristics for firm survival.

The rest of the paper is organized as follows. Section 2 introduces the firm level data and variables used in the empirical investigation of firm characteristics for firm survival in the COVI-19 crisis. Section 3 presents the results from standard Probit regressions and compares them to the estimations from KRLS regressions. Section 4 concludes.

2 Data and discussion of variables

The firm level data used in this study are taken from the World Bank's Enterprise Surveys in 2019 and from the COVID-19 follow-up surveys conducted in 2020.[1] These surveys were conducted in a large number of countries all over the world. In this study we focus on countries from Europe. All countries with suitable data from the third follow-up survey are included in the study. This leaves us with data for eight countries: Bulgaria, Croatia, Czech Republic, Hungary, Italy, Poland, Portugal, and Romania.

The classification of firms as survivors or exits is based on question B.0[2] in the follow-up survey from 2020. Firms that participated both in the regular 2019 survey and in the follow-up surveys were asked "Currently is this establishment open, temporarily closed (suspended services or production), or permanently closed?" Firms that answered "permanently closed" in one of the follow-up surveys are classified as exits; firms that answered "open" in the third wave of the follow-up survey are considered to be survivors.

In the empirical investigation the link between firm survival and a number of firm characteristics that are expected n to be related to firm exit are looked at. Their link to firm survival, and the way they are measured here, is discussed below.

Firm size: Audretsch (1995, p. 149) mentions as a stylized fact from many empirical studies on exits that the likelihood of firm exit apparently declines with firm size (usually measured by the number of employees in a firm). This is theoretically linked to the hypothesis of "liability of smallness" from organizational ecology. A small size can be interpreted as a proxy variable for a number of unobserved firm

[1] The data from the World Bank Enterprise surveys are available free of charge after registration from the website https://www.enterprisesurveys.org/portal/login.aspx .

[2] The questionnaires of the regular 2019 survey and the follow-up survey sconducted in 2020 are available from the World Bank's Enterprise Survey web site referred to above.

characteristics, including disadvantages of scale, higher restrictions on the capital market leading to a higher risk of insolvency and illiquidity, disadvantages of small firms in the competition for highly qualified employees, and lower talent of management (Strotmann 2007). For Germany, Fackler, Schnabel and Wagner (2013) show that the mortality risk falls with establishment size, which confirms the liability of smallness.

Firm size is measured as the number of permanent, full-time individuals that worked in the establishment at the end of the last complete fiscal year at the time of the regular 2019 enterprise survey (see question I.1).

Firm age: Audretsch (1995, p. 149) mentions as another stylized fact from many empirical studies on exits that the likelihood of firm exit apparently declines with firm age, too. This positive link between firm age and probability of survival is labelled “liability of newness” and it is related to the fact that older firms are “better” because they spent a longer time in the market during which they learned how to solve the range of problems facing them in day-to-day business. For Germany, Fackler, Schnabel and Wagner (2013) find that the probability of exit is substantially higher for young establishments which are not more than five years old, thus confirming the liability of newness.

Firm age is measured as follows. In question B.5 of the regular survey in 2019 firms were asked “In what year did this establishment begin operation?”. Firm age is the difference between 2019 and the founding year.

Innovation: Josef Schumpeter (1942, p. 84) argued some 80 years ago that innovation plays a key role for the survival of firms, because it “strikes not at the margins of the profits and the outputs of the existing firms but at their foundations and their very lives”. Baumol (2002, p. 1) called innovative activity “a life-and-death matter for the firm.” This positive link between innovation and firm survival is found in a number of empirical studies. For example, Cefis and Marsili (2005) show that firms benefit from

an innovation premium that ceteris paribus extends their life expectancy; process innovation in particular seems to have a positive effect on firm survival.

In the regular survey in 2019 firms were asked whether during the last three years this establishment has introduced new of improved products and services (see question H1). Firms that answered in the affirmative are considered as product innovators. Similarly, firms were asked whether during the last three years this establishment introduced any new or improved process, including methods of manufacturing products or offering services; logistics, delivery, or distribution methods for inputs, products or services; or supporting activities for processes (see question H5). Firms that answered in the affirmative are considered as process innovators.

Exporter: Exporting can be considered as a form of risk diversification through spread of sales over different markets with different business cycle conditions or in a different phase of the product cycle. Therefore, exports might provide a chance to substitute sales at home by sales abroad when a negative demand shock hits the home market and would force a firm to close down otherwise (see Wagner 2013). Furthermore, Baldwin and Yan (2011, p. 135) argue that non-exporters are in general less efficient than exporters (younger, smaller and less productive) and that, as a result, one expects that non-exporters are more likely to fail than exporters.

A number of recent empirical studies look at the role of international trade activities in shaping the chances for survival of firms; Wagner (2012, p. 256ff.) summarizes this literature. As a rule the estimated chance of survival is higher for exporters, and this holds after controlling for firm characteristics that are positively associated with both exports and survival (like firm size and firm age). This might point to a direct positive effect of exporting on survival.

The firm is considered as an exporter if it reports any direct exports in question D.3 of the regular enterprise survey in 2019.[3]

Website: One firm characteristic that is often considered to be important for fim survival is online presence, i.e. having a website where potential customers can learn about, and order, goods or services when personal contacts are not possible due to quarantine and lockdown. Wagner (2021) uses firm level data from ten European countries collected in the World Bank's Enterprise Surveys in 2019 and from the COVID-19 follow-up surveys conducted in 2020 to investigate the link between web presence and firm survival, controlling for other determinants of firm exit. He reports a positive effect of web presence on firm survival.

In the regular 2019 survey firms were asked in question C22b "At present time, does this establishment have its own website or social media page?" Firms that answered "yes" are classified as firm with web presence.

Furthermore, firms are divided by broad sectors of activity (manufacturing, retail/wholesale, construction, hotel/restaurant, and services) based on their answer to the question for the establishment's main activity and product, measured by the largest proportion of annual sales (see question D1a1).

Descriptive statistics for all variables are reported for the whole sample used in the empirical investigation in Table 1.

[Table 1 near here]

[3] Note that the survey asked for the percentage share of exports in total sales, too. This information is not used here. A closer look at the answers reveals that the numbers reported have to be considered as "guesstimates" at best with many firms reporting numbers like 10, 20, 30 etc.

The average share of exits in all countries included here is 6.1 percent. This number varies widely between the countries. The share of exits is below 3 percent in the Czech Republic and in Hungary, compared to 12.5 percent in Italy and nearly 10 percent in Bulgaria. To control for this cross-country variation the empirical models include a set of country fixed effects.

3 Characteristics of survivors of COVID-19: Results from Probit vs. KRLS regression

To test for the links between the probability that a firm is a survivor in times of COVID-19 and firm characteristics, and to document the size of the differences, between firms that do and that do not survive the crisis, an empirical approach is applied that regresses a dummy variable (indicating whether the firm is a survivor or not) on a set of variables measuring the firm characteristics (discussed in detail in section 2) and a set of country fixed effects (to control for differences in the level of firm exit and other country characteristics).

(1) $\text{Firm exit}_i = a + ß*\text{firm characteristics}_i + c*\text{country}_i + e_i$

where i is the index of the firm, firm exit is a dummy variable with a value of 1 if the firm is closed in the COVID-19 crisis and zero else, firm characteristics are the characteristics listed in section 2, country are dummy-variables for the country of origin of the firm, and e is an error term.

3.1 Results from Probit regressions

In a first step, the empirical model outlined in (1) above is estimated using Probit, a standard parametric econometric model. Estimated average marginal effects and their p-values are reported in the first column of Table 2.

[Table 2 near here]

The big picture revealed by these estimates can be summarized as follows: In line with the expectations from theoretical arguments and results from earlier empirical investigations on firm survival and firm characteristics all estimated marginal effects on the probability of firm exit are negative. In three cases, however, these estimates are only marginally significant statistically at a conventional level (this holds for the two innovation variables and the exporter dummy), and the effect of firm size cannot be considered to be different from zero.

3.2 Results from Kernel Regularized Lest Squares (KRLS) regressions

In the standard parametric model used in section 3.1 the firm characteristics that explain the survival of a firm intimes of COVID-19 enter the empirical model in linear form. This functional form which is used in hundreds of empirical studies for firm survival, however, is rather restrictive. If any non-linear relationships (like quadratic terms or higher order polynomials, or interaction terms) do matter and if they are ignored in the specification of the empirical model this leads to biased results. Researchers, however, can never be sure that all possible relevant non-linear relationships are taken care of in their chosen specifications. Therefore, this note uses the Kernel Regularized Least Squares (KRLS) estimator to deal with this issue. KRLS is a machine learning method that learns the functional form from the data. It has been

introduced in Hainmueller and Hazlett (2014) and Ferwerda, Hainmueller and Hazlett (2017), and used to estimate empirical models with firm-level data for the first time in Wagner (2025).

While a comprehensive discussion of the Kernel Regularized Least Squares (KRLS) estimator is far beyond the scope of this applied note, a short outline of some of the important features and characteristics might help to understand why this estimator can be considered as an extremely helpful addition to the box of tools of empirical trade economists (see Wagner (2025)). For any details the reader is referred to the original papers by Hainmueller and Hazlett (2014) and Fernwerda, Hainmueller and Hazlett (2017).

The main contribution of the KRLS estimator is that it allows the researcher to estimate regression-type models without making any assumption regarding the functional form (or doing a specification search to find the best fitting functional form). As detailed in Hainmueller and Hazlett (2014) the method constructs a flexible hypothesis space using kernels as radial basis functions and then finds the best-fitting surface in this space by minimizing a complexity-penalized least squares problem. Ferwerda, Hainmueller and Hazlett (2017) point out that the KRLS method can be thought of in the “similarity-based view” in two stages. In the first stage, it fits functions using kernels, based on the assumption that there is useful information embedded in how similar a given observation is to other observations in the dataset. In the second stage, it utilizes regularization, which gives preference to simpler functions (see Ferwerda, Hainmueller and Hazlett (2017), p.3).

KRLS works well both with continuous outcomes and with binary outcomes. It is easy to apply in Stata using the `krls` program provided in Ferwerda, Hainmueller and Hazlett (2017). Instead of doing a tedious specification search that does not guarantee a successful result, users simply pass the outcome variable and the matrix

of covariates to the KRLS estimator which then learns the target function from the data. As shown in Hainmueller and Hazlett (2014), the KRLS estimator has desirable statistical properties, including unbiasedness, consistency, and asymptotic normality under mild regularity conditions. An additional advantage of KRLS is that it provides closed-form estimates of the pointwise derivatives that characterize the marginal effect of each covariate at each data point in the covariate space (see Ferwerda, Hainmueller and Hazlett (2017), p. 11). These estimates can be used to examine the heterogeneity of the marginal effects.

Therefore, KRLS is suitable to estimate empirical models when the correct functional form is not known for sure – which is usually the case because we do not know which polynomials or interaction terms matter for correctly modelling the relation between the covariates and the outcome variable.

Results for an application of KRLS to the model for exit of a firm in the COVID-19 crisis are reported in the second to fifth columns of Table 2.

All estimated average marginal effects of firm characteristics reported in the second column have again a negative sign as in the case of the Probit results reported in first column of Table 2. Furthermore, the estimated size of the marginal effects from KRLS and Probit tends to be rather similar for firm characteristics measured by dummy variables (product and process innovation, exporter, and web site), while the statistical significance tends to be considerably smaller in KRLS. Results for firm age and firm size, however, do differ considerably. KRLS results point to a statistically highly significant positive link between firm size and firm survival (and the estimated marginal effect is more than twice as large in the KRLS model than in the Probit model). The estimated effect of firm age, on the other hand, is much smaller according to KRLS than from the Probit estimate.

These differences in the size and statistical significance of the average marginal effects between the results from Probit and KRLS regression can be explained by the fact that the parametric model in column 1 inappropriately imposes a restrictive functional form in the shape of the estimated relationships, while KRLS estimated this relationship without imposing such a functional form.

An additional advantage of KRLS compared to the Probit model is that it provides closed-form estimates of the pointwise derivatives that characterize the marginal effect of each covariate at each data point in the covariate space (see Ferwerda, Hainmueller and Hazlett (2017), p. 11). The last three columns of Table 2 report the marginal effects estimated by KRLS at the 1st quartile, at the median, and at the 3rd quartile. We can clearly see the heterogeneity in the marginal effects. The estimated marginal effects differ widely over the quartiles and tend to increase considerably for all variables considered here. This shows the nonlinearity and heterogeneity of the relationship between the covariates and firm exit in the COVID-19 crisis.

4 Cocluding remarks

This note looks at the links between firm characteristics and the probability of firm exit during the COVID-19 crisis. It estimates an empirical model and applies two methods to do so, a standard parametric Probit model and a a machine learning method that learns the functional form of the model from the data, namely Kernel Regularized Least Squares (KRLS). It turns out that results from both methods do differ considerably for the two firm characteristics that are measured by continuous variables (firm age and firm size).

These differences in the size and statistical significance of the average marginal effects between the results from Probit and KRLS regression can be explained by the

fact that the Probit model inappropriately imposes a restrictive functional form in the shape of the estimated relationship, while KRLS estimates this relationship without imposing such a functional form.

The take-home message, then, is: Whenever you estimate an empirical model that links an outcome variable to a set of potential determinating factors take care of non-linear relatonships and interaction terms in investiagting the sign, size and statistical significance of the marginal effects of these variables on the outcome – and let kernel regularized least squares (KRLS) do this job in a both conviniant and convincing way.

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Table 1: Descriptive statistics for sample used in estimations

Variable	Mean	Std. Dev.
Firm exit (Dummy; 1 = yes)	0.0608	0.2390
Firm age (Years)	23.0	17.00
Firm size (Number of employees)	71.33	150.28
Product innovator (Dummy; 1 = yes)	0,2204	0.4146
Process innovator (Dummy; 1 = yes)	0.1055	0.3073
Exporter (Dummy; 1 = yes)	0.3034	0.4598
Web-presence (Dummy; 1 = yes)	0.7179	0.4501
Manufacturing (Dummy; 1 = yes)	0.6425	0.4793
Retail / Wholesale (Dummy; 1 = yes)	0.1861	0.3892
Construction (Dummy; 1 = yes)	0.0547	0.2274
Hotel / Restaurant (Dummy; 1 = yes)	0.0350	0.1837
Services (Dummy; 1 = yes)	0.0817	0.2739
Number of observations	4,406	

Source: Own calculations with data from World Bank Enterprise surveys; for details see text.

Table 2: Empirical results

Dependent variable: Firm exit (Dummy; 1 = yes)

Method	Probit Average marginal effects	KRLS Average marginal effect	P25	P50	P75
Firm age (years)	-0.037 (o.000)	-0.00067 (0.002)	-0.0010	-0.00066	-0.00029
Firm size (Number of employees)	-0.000043 (0.468)	-0.000093 (0.000)	-0.00013	-0.000098	-.000067
Product innovation /Dummy; 1 = yes)	-0.014 (0.111)	-0.012 (0.226)	-0.022	-0.0087	0.00093
Process innovation (Dummy; 1 = yes)	-0.019 (0.089)	-0.011 (0.384)	-0.017	-0.0063	0.0018
Exporter (Dummy; 1 = yes)	-0.016 (0.072)	-0.014 (0.139)	-0.027	-0.010	0.0006
Web site (Dummy, 1 = yes)	-0.037 (0.000)	-0.036 (0.000)	-0.055	-0.030	-0.014
Sector and country dummies	included	included			
Number of cases	4,406				

Note: Probit reports average marginal effects from a model estimated by ML Probit. KRLS reports average marginal effects and marginal effects at the 25th, 50th and 75th percentile estimated by kernel regularized least squares. P-values are reported in parentheses. For details, see text.

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