International Review of Economics and Finance 69 (2020) 860–878

Contents lists available at ScienceDirect

International Review of Economics and Finance

journal homepage: www.elsevier.com/locate/iref

Bank survival in Central and Eastern Europe

Evžen Kočenda [a,b,c,*], Ichiro Iwasaki [d]

[a] Institute of Economic Studies, Charles University, Opletalova 26, 110 00, Prague, Czech Republic
[b] CESifo, Munich, Germany
[c] IOS, Regensburg, Germany
[d] Institute of Economic Research, Hitotsubashi University, Naka 2-1, Kunitachi, Tokyo, 186-8603, Japan

ARTICLE INFO

JEL classification:
C14
D02
D22
G33

Keywords:
Bank survival
Banking reform
Central banks
Central and Eastern Europe
Emerging markets
Survival and exit determinants
Hazards model

ABSTRACT

We analyze factors linked to bank survival on large dataset covering 17 CEE markets during the period of 2007–2015 by estimating the Cox proportional hazards model. We group banks across countries and according to their financial soundness. The overall financial development improves survival probabilities and its impact exhibits decreasing marginal returns as it is strongest in countries with lower level of financial development and banking reforms and in banks with low level of solvency. Measures of ownership structure, legal form, and corporate governance are the key economically significant factors that exhibit strongest economic effect on bank survival. Financial performance indicators predict bank survival rate with intuitively expected positive impact but their effect, in terms of economic significance, is smaller in comparison to other factors as well as the impact found in developed markets. Effect of above factors is most pronounced for banks with low financial soundness in term of their solvency. Results also appear to indicate that it makes exit more likely during the global financial crisis, shortly afterwards, and during the initial stage of the European sovereign debt crisis. This result is critical for central banks due to their regulatory and governance mandate. The results are robust with respect to size, age, and alternative assumptions on survival distribution.

1. Introduction

Banks are the key institutions to mediate flow of funds in economy. Their stability is thus of essential significance because when their survival becomes seriously troubled, a cost-effective solution might be to bail them out as failure would exert costly and damaging effects on the economy (Gerlach et al., 2010).[1] Knowledge of the factors linked to predictions of bank survival is then naturally critical for central banks as regulators in order to provide early warnings. While the subject is relatively well mapped in developed and some emerging countries (reviewed presently), it is lacking ground in Central and Eastern Europe (CEE) where private banks emerged as part of economic transformation during the 1990s (Bonin et al., 2015). For that, our key question is whether and how did banking reform and financial development in general, as a major factor, affect bank survival in the CEE region.

The lack of bank survival research in CEE is troubling for several reasons. Banking industry in CEE economies is closely connected with that in founding member states of the European Union (EU) - commercial banking sectors in the CEE countries developed as part of their economic transformation and banks from the founding EU countries became major shareholders in CEE banks (Bonin et al., 2005;

* Corresponding author. Institute of Economic Studies, Charles University, Opletalova 26, 110 00, Prague, Czech Republic.
E-mail addresses: evzen.kocenda@fsv.cuni.cz (E. Kočenda), iiwasaki@ier.hit-u.ac.jp (I. Iwasaki).

[1] Indeed, many European banks received state interventions during the 2008-09 global financial crisis (Abreu et al., 2019).

https://doi.org/10.1016/j.iref.2020.06.020
Received 31 July 2019; Received in revised form 11 March 2020; Accepted 15 June 2020
Available online 3 July 2020
1059-0560/

Fungáčová & Weill, 2013). Due to this interlinkage, spillovers of distress are likely to impact bank survival in CEE. Further, after the global financial crisis (GFC) failing banks directly impact the level of sovereign risk in Europe, and in the CEE economies in particular (Brůha & Kočenda, 2018; Singh et al., 2016). Bank failures and survival thus potentially affect extent of government interventions evidenced in Europe (Abreu et al., 2019). These interventions further increase government debt that is shown to have detrimental effects on growth in Europe well before the Stability and Growth Pact debt ceiling is reached (Gómez-Puig and Sosvilla-Rivero, 2017). Finally, Platt and Platt (2008) show that financial distress, that preceeds bankruptcy, differs across world regions. Hence, similar factors do not influence corporate financial strength equally in all countries. Economic and institutional differences of the CEE region then suggest that factors behind bank survival might differ as well.

Knowledge of factors linked to bank survival is of importance not only for regulators in CEE but in Europe as a whole and for that we analyze the impact of a set of theoretically and empirically grounded factors linked with the bank survival in individual CEE banks. In our assessment we focus on period from 2007 onwards as there is no contemporary analysis of the bank survival covering banks in large CEE region during the GFC and later on. Our aim is to provide such empirical assessment that is yet missing in the literature.

There is substantial literature on linking characteristics of individual banks with their probabilities to fail or survive. Particularly well covered is the U.S. banking sector. In a seminal paper, Lane et al. (1986) analyzed survival predictions on a moderate sample of the U.S. banks, employing standard financial ratios, and showed better predictive power of the Cox proportional hazards model over a discriminant analysis; Whalen (1991) and Wheelock and Wilson (2000) followed a similar strategy and showed similar results based on a wider sample coverage. Further additions mapping the survival of the U.S. banks include, for example, Cole and Gunther (1995), Hwang et al. (1997), Calomiris and Mason (2003), DeYoung (2003), Cebula (2010), Cole and White (2012), Berger and Bouwman (2013), and Carmona et al. (2019). Those studies employ varying sets of standard financial indicators, additional bank-specific variables (size, age, corporate structure, etc.), and various (macro)economic controls. The literature based on the U.S. banks shows that standard financial indicators of a bank's condition are important in explaining bank failure, and various proxies for economic developments (real estate investments, unemployment, stock market volatility etc.) often improve predictions. These findings further motivate our approach, in which we do not employ only financial ratios but also wider set of factors that we detail presently.

Bank failure issues are covered in number of developed as well as emerging markets by Evrensel (2008) and Fiordelisi and Mare (2013). However, emerging markets worldwide are much less covered, potentially because of the fact that the data are not that readily available. Still, the contributions to the literature cover bank failures in various emerging markets including Venezuela (Molina, 2002), Russia, (Carree, 2003; Fungáčová & Weill, 2013; Peresetsky et al., 2011), Argentina (Dabós & Escudero, 2004), Croatia (Kraft & Galac, 2007), Brazil (Alves et al., 2014; Sales & Tannuri-Pianto, 2007), Nigeria (Babajide et al., 2015), East Asian countries (Lin & Yang, 2016), and Middle and Far Eastern countries (Alandejani et al., 2017; Pappas et al., 2017).

Many of the above studies are in line with those covering the U.S. banking sector in that they show importance of widely used indicators of financial performance. On the other hand, some of the studies accentuate other factors – for example, Fungáčová and Weill (2013) show that tighter bank competition enhances the occurrence of bank failures; Lin and Yang (2016) accentuate the role of favorable macroeconomic conditions for length of bank survival, but they also stress that in terms of survival probability bank fundamentals play a more critical role than do macroeconomic situations. The above studies also motivate our approach to consider an aggregate extent of financial development as potential source of bank (in)stability. Despite of the cited studies, we have to stress, that no multi-country survival study covering banks in the CEE markets after the global financial crisis is available so far.[2]

In this sense, our analysis brings a recent evidence and directly contributes to the above strand of literature. The list of novelties can be summarized in that (i) we provide assessment of a set of factors linked to bank survival rates (rather than distress predictions) and among them we also specifically include a composite measure of financial development that accounts for progress in banking reform as well as measurable aggregate development of banking sector in each country under research. Further, and quite importantly, (ii) we cover a recent period of the Global Financial Crisis and European Sovereign Debt Crisis.[3] Finally, (iii) we derive our results by employing a versatile technique that does not require assumptions on the baseline hazard function (details are provided presently in Section 2).[4]

Specifically, we assess how various bank-related factors affect bank survival with a flexible survival model that does not require to

[2] An earlier analysis investigating the bank distress in 19 Eastern European transition economies over the period 1995–2004 was brought by Männasoo and Mayes (2009). They use a complementary log-log (cloglog) hazard model with set of macroeconomic, structural and bank-specific variables to predict distress vulnerabilities in banking sectors of European transition countries and show that many factors related to bank soundness exhibit dependable distress detection ability. In our analysis we do not provide a simple follow-up despite that, quite naturally, we partially overlap with their bank-specific variables and country sample. On contrary, we contribute to the literature by differentiating on more principal grounds. Männasoo and Mayes (2009) cover 10 new-EU member states (Bulgaria, Czech Republic, Estonia, Hungary, Latvia, Lithuania, Poland, Romania, Slovenia, and Slovakia), plus Albania, Belarus, Bosnia, Croatia, Former Yugoslav Republic of (FYR) Macedonia, Moldova, Serbia, Russia, and Ukraine. We cover the same 9 new-EU countries (except for Slovenia), plus Bosnia, Croatia, FYR Macedonia, Moldova, Montenegro, Serbia, Russia, and Ukraine. Hence, Männasoo and Mayes (2009) do not cover Montenegro, while we do not cover Albania, Belarus, and Slovenia (due to some inadequacies in data availability.

[3] The overall negative impact of the GFC on banks is sufficiently documented in the literature (Claessens & Van Horen, 2015). European sovereign debt crisis also excerts potential to negatively affect bank survival rate via different channels. For example, negative impact of the European sovereign debt crisis on European banks' equity returns along with evidence of shift contagion across Europe is shown by Allegret et al. (2017). Further, banks in the EU hold on average 9% of their total assets in a form of sovereign debt (Gennaioli et al., 2018); hence, sovereing debt crisis directly and negatively impacts bank's assets.

[4] Männasoo and Mayes (2009) employ a cloglog hazard model that requires distributional assumptions but they do not provide information on distributional assumptions.

proxy for failure risk and allows for time-varying failure probability. In our analysis we employ the semiparametric Cox proportional hazards model (Cox, 1972); details are provided in Section 2.1. It is a distribution-free technique that is more convenient than other tools since it does not require any distributional assumptions and delivers better comparison of the results than shown in previous literature (Pappas et al., 2017). It is an established technology in empirical survival literature (Manjón-Antolín & Arauzo-Carod, 2008) and has been used in number of bank-related studies (Henebry, 1996), including many of those cited above.

We are aware that our sample of 17 countries exhibits some heterogeneity in economic, social, and political characteristics. For robustness of our analysis we divide banks in two principal and non-arbitrary ways in order to use information potential contained in the data. First, we divide banks according to country groups that reflect geography of the CEE markets, differences in economic development, as well as former transition experiences (EU countries, Russia/Ukraine, Non-EU countries). Second, we divide banks into groups based on their soundness represented by combination of some key financial criteria used in other bank-survival studies (Aliyu & Yusof, 2017; Lane et al., 1986; Pappas et al., 2017). Details on the group composition along with the number of banks covered in specific groups are provided in Section 3.

In our assessment of the bank survival we employ number of qualitatively different types of factors. First, importance of the regulatory reform on bank survival was shown by Santarelli (2000) or Alandejani et al. (2017); for that we hypothesize that banking sector related financial development in each country should exhibit economically significant impact on bank ability to survive as it represents a degree of cultivation and regulation of the banking industry and its institutions. At the same time, the progress in the undertaken banking reforms and financial development represents a useful control to account for unobserved country-specific heterogeneity present even after dividing banks into country-based or soundness-based groups. Second, Goddard et al. (2009) argue that firm-specific factors are most important in explaining variations in firm performance. Therefore, we extend such idea to assess the impact of bank-specific characteristics on bank survival. We control for bank-specific factors by employing a number of theoretically and empirically grounded factors that capture financial, legal, ownership, governance, and performance characteristics of banks. The factors are detailed later on in the data section where we also indicate hypothesized effects that the variables are expected to impart.

Our paper contributes to the existing literature on bank survival by analyzing a large dataset of banks and financial institutions from 17 CEE countries during periods of global financial crisis and European sovereign debt crisis. Our findings are based on estimating the Cox proportional hazards model on banks that are grouped in two qualitatively different sets. The vital result shows that the development of the banking sector is an important factor positively affecting bank survival. Further, we show that financial measures of bank soundness are often helpful factors (as documented in developed markets) but ownership structure and legal form are the key economically significant factors that are behind bank survival in the CEE region. This finding shows that unique transformation experience of the CEE countries and their banks might impart its legacy. These results are robust across bank groups, with respect to alternative specifications, as well as alternative assumptions on survival distribution.

The remainder of the paper is organized as follows. In Section 2, we describe the data and applied methodology. In Section 3, we bring forth extensive and detailed results. Section 4 concludes.

2. Data and methodology

2.1. Data coverage

Our dataset allows us to trace the survival status of banks and financial institutions from 17 countries in the Central and Eastern Europe (CEE) and former Soviet Union (FSU) along with the additional bank-specific information detailed later in this section; we use a common term bank as a matter of convenience. The large dataset contains a total of 12, 688 bank-year observations and from perspective of economic and transformation development the countries are divided into three groups. Group I consists of the EU-member countries (Bulgaria, Croatia, Czech Republic, Estonia, Hungary, Latvia, Lithuania, Poland, Romania, and Slovakia); Group II is formed by two large FSU countries (Russia and Ukraine); Group III consists of five small Eastern European countries (Bosnia, FYR Macedonia, Moldova, Montenegro, and Serbia). In Fig. 1 we provide details on the numbers of failed bank-year observations in each country group along with the dynamics of the exit rate; there is a total of 3, 934 exits. The size of the sample is different across groups. However, the exit rate displayed in each panel shows a normalized value of firm failure against the difference in a sample size. For that, difference in sample size across groups does not result in difference with respect to the comparisons and trends.

Further, the set of bank-specific variables representing bank survival determinants is assembled from the Bureau van Dijk's Orbis database. The key advantage of the Orbis database is that it retains data also for inactive firms, an important property for survival analysis. Banks and financial institutions included in our dataset strictly satisfy two conditions: (i) they were in business at the end of 2006 (i.e., before the global financial crisis), and (ii) they provided information about their survival status at the end of 2015. Similarly as Chiaramonte and Casu (2017) or Aliyu and Yusof (2017) we classify failed banks as those being liquidated, bankrupt, and/or dissolved. Banks in the category of mergers/acquisitions are not considered as failed.[5] Bailed-out banks were excluded from the sample.

In the account below, we detail the variables used, along with hypothesized effects that the variables are expected to produce. Positive effect (+) indicates that a factor is expected to increase bank survival chances. The decrease of survival chances is associated

[5] Since banking sectors in CEE markest are still in process of catching-up with developed countries, we do not consider banks in the category of mergers/acquisitions as having failed because these transactions are frequently associated with changes in ownership structure rather than bank performance. Lanine and Vander Vennet (2007) show that large Western European banks have targeted relatively large and efficient Central and Eastern European countries (CEEC) banks with an established presence in their local retail banking markets and find no evidence that cross-border bank acquisitions in the CEEC are driven by efficiency motivations.

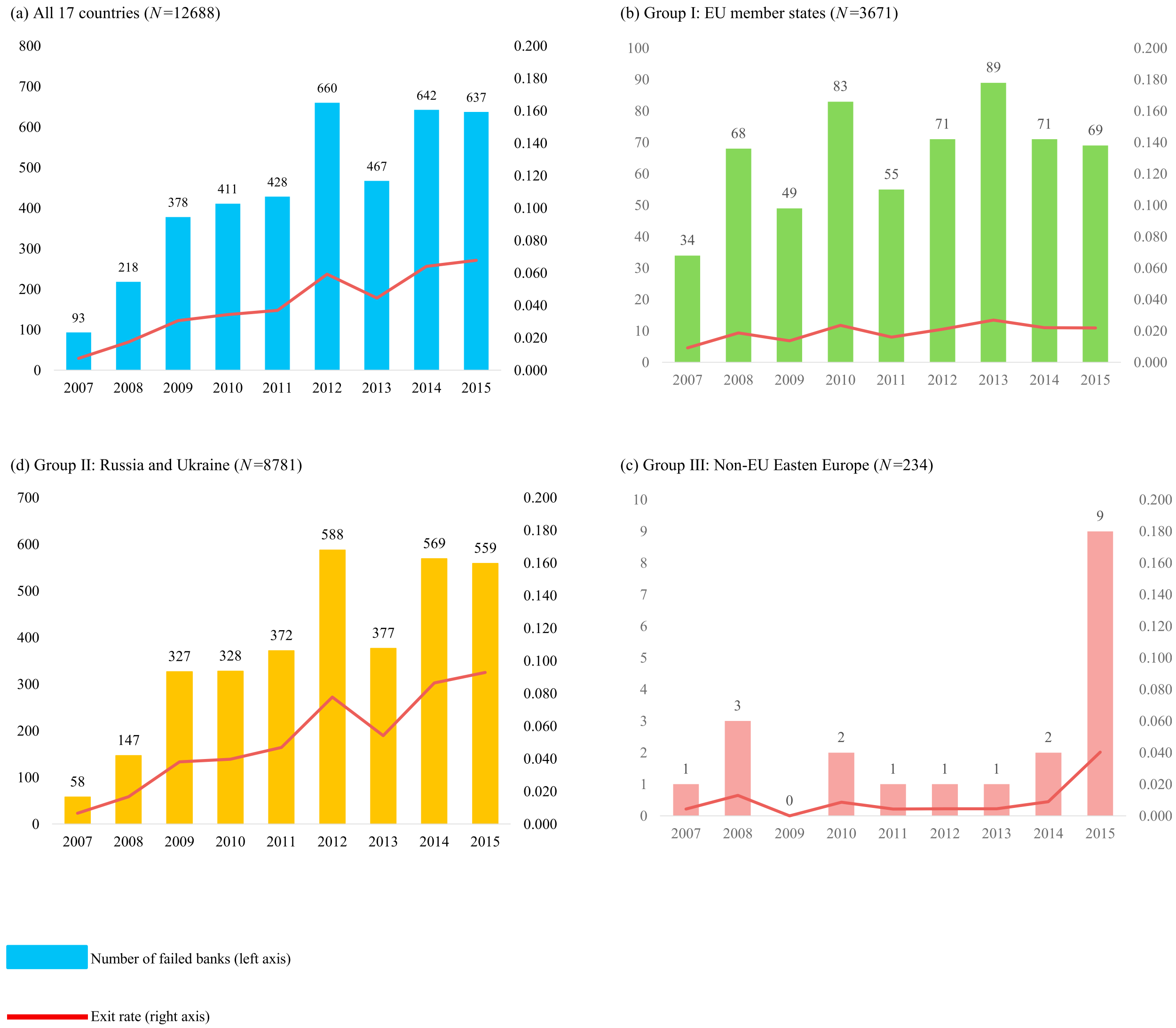

Fig. 1. Number of failed banks and, exit rate by country group and year, 2007–2015.

with a negative effect (−). Variable are described as two categories: (1) indicators of financial development in a country, (2) firm characteristics, ownership and financial indicators.

2.1.1. Indicators of financial development

In order to capture the development of the banking sector we employ four different indicators of the financial development. One, we use the "Banking reform and interest rate liberalisation" indicator of the European Bank for Reconstruction and Development (EBRD). The indicator provides ranking of progress in individual countries in terms of liberalisation and institutional reforms in the banking sector under the regulatory supervision of central banks on a scale from 1 to 4+ (EBRD, 2007, p. 211). A score of 1 denotes a little progress beyond establishment of a two-tier system. A score of 2 marks a significant liberalisation of interest rates and credit allocation; limited use of directed credit or interest rate ceilings. A score of 3 represents a substantial progress in establishment of bank solvency and of a framework for prudential supervision and regulation; full interest rate liberalisation with little preferential access to cheap refinancing; significant lending to private enterprises and significant presence of private banks. A score of 4 means significant movement of banking laws and regulations towards the Bank for International Settlements (BIS) standards; well-functioning banking competition and effective prudential supervision; significant term lending to private enterprises; substantial financial deepening. Finally, a score of 4+ represents standards and performance norms of advanced industrial economies: full convergence of banking laws and regulations with BIS standards; provision of full set of competitive banking services.

The other three financial indicators are more orthodox variables employed in the financial literature to capture the level of financial development in a country. They include: liquid liabilities, private credit, and bank credit. The variable of liquid liabilities contains ratio of liquid liabilities to GDP. Liquid liabilities are also known as broad money, or M3. The variable of private credit denotes the financial resources provided to the private sector by domestic money banks as a share of GDP. Domestic money banks comprise commercial banks and other financial institutions that accept transferable deposits, such as demand deposits. The variable of bank credit is defined as private credit by deposit money banks and other financial institutions to GDP. We obtained the values of these three variables from the Global Financial Inclusion Database of the World Bank.

In order to gauge the aggregate effect of financial development in each country we construct a comprehensive financial development (CFD) index from all four variables related to development of the banking sector. We proceed by performing a principle component analysis (PCA) to capture the potential structure behind financial development. This step has two advantages: we can analyze the aggregate impact of four various factors without omitting any particular one and we avoid correlations among (Table A.1). To eliminate problem of different scales, we normalize the four indicators so that they provide comparable impact of financial development independently of their original scale. The PCA results are presented in Panel a of Table A.2. All financial sector variables exhibit similar eigenvector values. Furthermore, the PCA results show that the first component alone explains 83.5 percent of total variance among the four variables. Hence, we can confidently say that the first component is a suitable proxy for the aggregate level of financial development in countries under research and as such we use it as our CFD index.

We hypothesize that the overall extent of financial development and progress in banking reform is associated with a positive effect on survival probability (+). In the estimation stage we use the CDF index as our key measure of the financial development. Further, we also estimate the model with four indicators separately. This is done (i) to see differences in impact that specific indicators are likely to produce, and (ii) to prevent simultaneity issue due to the correlation between the four indicators that ranges within 0.61–0.89 interval (Table A.1).

2.1.2. *Firm characteristics, ownership and financial indicators*

Further, we employ several variables that are frequently used as measures of bank soundness and represent a subset of the CAMELS factors; CAMELS is an acronym for Capital adequacy, Asset quality, Management soundness, Earnings and profitability, Liquidity, and Sensitivity to market risk. The CAMELS variables were also used in earlier as well as recent bank-survival studies (Lane et al., 1986; Cole and White, 2012; Pappas et al., 2017; Aliyu & Yusof, 2017; Carmona et al., 2019). The CAMELS rating provides essential information on the overall condition of a bank in a numerical form (Peek et al., 1999); the expected effects are shown below in parentheses. Because we do not have data available on the full set of the CAMELS factors for all banks, the following variables are used as the closest proxies: Capital adequacy (C) proxied with a solvency ratio (+),[6] Asset quality (A) proxied with returns on assets – ROA (+),[7] Earnings (E) proxied with net profit margin (±), Liquidity (L) proxied with liquidity ratio (+)[8]; the data are not readily available to cover Management (M) and Sensitivity (S) categories.

Each firm has to be established and function in a specific legal form. Therefore, we differentiate between joint-stock company (?) and limited liability company (+) that represent the two most frequent legal forms among the financial institutions in our sample. A legal form might play a role with respect to bank survival because survival probability should be assessed primarily from the perspective of how each legal form enables to deal with profits and losses. For example, a limited liability form is hypothesized to be associated with positive impact on survival probability because the burden to deal with losses is upper-limited by the law.

In terms of the ownership structure we introduce categorical variables to separate the effects of foreign (+), state (−), and private (+) ownership. Foreign ownership is based on the domicile of the foreign owner who effectively exercises control over a firm, and private (domestic) ownership is considered as residual (default).

In addition, we account for the corporate governance by using the number of board directors (+) along with its non-linear effect (−). The hypothesized inverted U-shape pattern between the board size and survival probability is based on the arguments in De Andres and Vallelado (2008; p. 2571) who argue that "larger board facilitates manager supervision and brings more human capital to advise managers. However, boards with too many members lead to problems of coordination, control, and flexibility in decision-making."

Finally, we employ variables to control for further bank-specific characteristics: size of the bank represented by total assets (+; DeYoung, 2003), information whether a bank is listed on a stock exchange, meaning how tightly the bank is connected with capital market (+), and the age of the bank (+) that is counted from its establishment in case of private bank, and from its reorganization in case of a privatized bank.[9] The mean of the beginning year of bank operation is 1996 and the latest one is 2006 – the numbers correspond to the fact that many of the banks in our sample went through transformations prior to 2006. Details and descriptive statistics are presented in Table 1.

[6] We use the Solvency ratio (Shareholders funds/Total assets) as a proxy for Capital adequacy; this is consistent with the Equity/Total assets measure. The Solvency ratio is a capital ratio that reflects a new non-risk based capital measure "Leverage ratio" introduced by the Bank for International Settlements (BIS, 2014). We acknowledge that Capital quality is typically proxied by Tier 1 Ratio, or Total Capital ratio – these measures are not consistently available across our sample, though.

[7] We employ the indicator in the same way as Betz, Oprica, Peltonen, and Sarlin (2014) for European banks (Asset quality (A) is represented by ROA). Higher returns on assets mean not only better performance of a bank, but the measure also indicates a lower proportion of the non-performing assets (non-performing loans) of the bank, indicating better asset quality and lower credit risk associated with it. No other more suitable proxy (e.g. non-performing loans) for the Asset quality is available in sufficient extent and consistently across the banks in our sample.

[8] Correlations between profit margin, ROA, liquidity ratio and solvency ratio range between 0.07 and 0.55 and do not lead to problem of multicollinearity.

[9] The variable of firm age represents the number of years of operation until the end of 2006; it does not account for subsequent years from 2007 onward. Hence, the age does not represent time in usual sense and the age is not used to sort the data in the estimation process.

2.2. Cox proportional hazards model

We estimate the potential effects of various factors on a bank's failure through a survival model; indicators are reported in Table 1. Survival models bypass the necessity of proxies to capture bank failure risk that might preclude accurate comparison. Further advantage is that, in comparison to the standard logit models, survival models allow for the probability of the bank failure to vary over time. Specifically, we employ the Cox proportional hazards model (Cox, 1972) because the technique does not require assumptions on the baseline hazard function (unlike parametric survival models) and the results do not suffer incorrect assumption bias (Pappas et al., 2017).[10] This feature makes it an effective tool and the most commonly used model in empirical survival literature (Manjón-Antolín & Arauzo-Carod, 2008). The Cox technique uses a time-to-failure as an observable variable.

The Cox proportional hazards model assumes that the hazard denoting the probability of an event (bank exiting the market) $h_0(t)$ depends on time t and a set of relevant covariates x_{in}:

$$h(t|x_{i1},\ldots,x_{in}) = h_0(t)\exp(\beta_1 x_{i1} + \beta_2 x_{i2} + \ldots + \beta_n x_{in}) = h_0(t)\exp(x^T\beta), \quad h_0(t) > 0 \tag{1}$$

where β_1, β_2, …, and β_n are the parameters to be estimated. Specification (1) defines the hazard rate at time t for subject i, which depends on a vector of covariates $\boldsymbol{x}$. Considering two observations, i and $\check{i}$, that differ in their covariates (values of x_i), with the following linear representation:

$$\eta_i = \beta_1 x_{i1} + \beta_2 x_{i2} + \ldots + \beta_n x_{in} \tag{2}$$

and

$$\eta_{i}^{`} = \beta_1 x_{i1}^{`} + \beta_2 x_{i2}^{`} + \ldots + \beta_n x_{in}^{`} \tag{3}$$

then the so-called hazard ratios for these two observations are defined as (note that they are independent of time t):

$$\frac{h_i(t)}{h_{i^`}(t)} = \frac{h_0(t)\exp(\eta_i)}{h_0(t)\exp(\eta_{i^`})} = \frac{\exp(\eta_i)}{\exp(\eta_{i^`})} \tag{4}$$

Estimates of parameters β are obtained from the maximum likelihood estimation of the logarithmic transformation of specification (1), which is represented by the following linear model:

$$\ln h(t|x_{i1},\ldots,x_{in}) = \ln h_0(t) + \sum_{j=1}^{n} b_j x_{ij} \tag{5}$$

Variables in (5) are defined in the same way as in (1).[11]

Our estimation strategy follows examples of approaches adopted recently by Esteve-Pérez et al. (2004), Taymaz and Özler (2007), Iwasaki (2014), Iwasaki and Kočenda (2020), and Baumöhl, Iwasaki, and Kočenda (2019, 2020). In our results, we will present each parameter β in the form of a hazard ratio, due to its straightforward interpretation—a hazard ratio indicates how the probability of a bank exiting the market is multiplied when a specific covariate x (e.g., a bank survival determinant in a form of an independent variable) changes by one unit. If an estimate is over 1, we may consider a determinant (covariate x) to be a risk factor, increasing the probability of bank's exit. Similarly, if an estimate is below 1, such a determinant (covariate) is considered to be a preventive factor inhibiting a bank's exit from the market. Statistically significant estimates below 1 are economically more significant preventive factors if they are further from 1; opposite applies to estimates larger than 1. A following example can serve as a useful illustration of the economic significance meaning. A statistically significant estimate of a hazard ratio denotes percent change in survival probability by a one-unit change of a covariate in question.[12] If we have two estimates of hazard ratios (of two covariates) with values of 0.9 (covariate A) and 0.8 (covariate B), then a unit improvement in these covariates is linked to a 10% (covariate A) and 20% (covariate B) increase in probability of firm survival, respectively, because 1–0.9 = 0.1 and 1–0.8 = 0.2. Since covariate B is associated with higher survival probability, it is economically more significant than is covariate A.

We acknowledge that under certain conditions an endogeneity issue may arise in the survival analysis. This happens if: (i) an independent variable is a future variable, (ii) the estimation period is very short, or (iii) the dependent variable is continuous (Liu, 2012). Under these

[10] Parametric survival models represent an empirical alternative but they require distributional assumptions for the baseline hazard. Differences in distributional assumption thus imply potential problems of misspecification. Sales and Tannuri-Pianto (2007) use exponential distribution to assess banks in Brazil. Evrensel (2008) uses Weibull distribution and provides results for number of developed as well as non-European emerging markets. Männasoo and Mayes (2009) employ a complementary log-log to analyze CEE markets but do not provide information on distributional assumptions.

[11] We control for heterogeneity by including a comprehensive financial development index that results from the principal component analysis described in sub-section 2.1.1. This way we control for differences in four important measures of banking sector development in each country. Further, in Table 2, we also report baseline results without comprehensive financial development index for specification including country-level fixed effects (column 1) and compare it with estimates without country-level fixed effects (column 2) – the coefficients are similar in magnitude and same in the impact direction. Based on the two approaches we feel that potential heterogeneity was accounted for.

[12] Statistical significance is assessed via the z statistics reported in parentheses beneath the hazard ratios. For all estimations we also report the results of the Wald test and show that all standard regression coefficients are statistically different from zero.

Table 1
Definitions, predicted impact on bank survival, and descriptive statistics of variables used in the empirical analysis.

Variable name	Definition	Predicted impact on bank survival[a]	Descriptive statistics											
			All 17 countries			Group I: EU member states			Group II: Russia and Ukraine			Group III:Non-EU Eastern Europe		
			Mean	S.D.	Median	Mean	S.D.	Median	Mean	S.D.	Median	Mean	S.D.	Median
Country-level financial variables														
Liquid liabilities	World Bank indicator of liquid liabilities to GDP[b]	+	−0.499	0.937	−1.180	0.609	0.961	0.538	−0.954	0.380	−1.180	−0.797	0.760	−1.210
Private credit	World Bank indicator of credit to private sector to GDP[b]	+	−0.497	0.581	−0.849	0.012	0.805	−0.217	−0.705	0.243	−0.849	−0.697	0.453	−0.817
Bank credit	World Bank indicator of private credit by deposit money banks to GDP[b]	+	−0.538	0.609	−0.935	0.018	0.801	−0.210	−0.766	0.284	−0.935	−0.687	0.451	−0.807
Banking reform	EBRD index of banking sector reform	+	3.059	0.484	2.700	3.756	0.291	3.700	2.778	0.132	2.700	2.700	0.000	2.700
Comprehensive FD index	First principal component score of the six FD variables above	+	0.000	1.828	−1.361	2.202	1.790	2.651	−0.898	0.780	−1.361	−0.827	1.057	−1.326
Firm-level variables														
Joint-stock company	Dummy variable for joint-stock companies	?	0.220	0.414	0	0.141	0.348	0	0.249	0.432	0	0.380	0.487	0
Limited liability company	Dummy variable for limited liability companies	+	0.444	0.497	0	0.444	0.497	0	0.452	0.498	0	0.154	0.362	0
Foreign ownership	Dummy for firms with foreign ownership	+	0.046	0.210	0	0.106	0.308	0	0.017	0.128	0	0.056	0.230	0
State ownership	Dummy for firms with state ownership	?	0.119	0.323	0	0.033	0.179	0	0.156	0.363	0	0.205	0.405	0
Number of board directors	Number of recorded members of the board of directors	+	1.996	2.690	1	3.149	3.796	2	1.462	1.724	1	3.962	4.428	2
Number of board directors_squared	Squared number of recorded members of the board of directors	–	11.219	66.050	1	24.317	114.640	4	5.110	22.981	1	35.218	77.981	4
ROA	Return on total assets (%)[c]	+	5.704	19.886	1.830	6.491	16.547	2.280	5.525	20.982	1.670	1.877	16.227	0.850
Profit margin	Profit margin (%)[d]	+	4.866	22.588	2.715	7.428	19.519	3.730	3.889	23.192	2.290	9.289	33.220	11.680
Liquidity ratio	Liquidity ratio (%)[e]	+	2.704	7.134	1.000	1.999	4.780	1.090	2.928	7.722	0.990	3.527	8.915	0.890
Solvency ratio	Solvency ratio (%)[f]	+	43.475	39.722	41.650	43.834	34.485	41.875	43.286	41.598	41.465	45.963	32.261	40.240
Listed	Dummy variable for listed companies	+	0.022	0.145	0	0.020	0.141	0	0.005	0.067	0	0.675	0.469	1
Firm size	Natural logarithm of total assets in euros	+	7.575	2.249	7.490	8.197	2.491	8.005	7.328	2.060	7.298	8.619	3.568	8.968
Firm age	Years in operation until the end of 2006	+	10.759	10.933	9	15.459	16.051	11	8.530	5.791	8	20.727	23.544	14

Notes.
[a] +: Positive impact (i.e., hazard ratio is less than 1.0); -: Negative impact (i.e., hazard ratio is more than 1.0); ? Unpredictable.
[b] Standardized to have a mean of zero and a standard deviation of one (i.e., z score).
[c] Computed using the following formula: (profit before tax/total assets) × 100.
[d] Computed using the following formula: (profit before tax/operating revenue) × 100.
[e] Computed using the following formula: ((current assets - stocks)/current liabilities) × 100.
[f] Computed using the following formula: (shareholder funds/total assets) × 100.
Source: Country-level variables from liquid liabilities to bank credit were obtained from the website of the World Bank (https://data.worldbank.org/). Country-level variable of banking reform was obtained from EBRD website (http://www.ebrd.com/home). Firm-level raw data was extracted from the Bureau van Dijk (BvD) Orbis database (https://webhelp.bvdep.com).

Table 2
Baseline estimation of the Cox proportional hazards model.

Target country	All 17 countries						
Model	[1]	[2]	[3]	[4]	[5]	[6]	[7]
Country-level financial development							
Liquid liabilities			0.78439***				
			(−9.02)				
Private credit				0.90955**			
				(-2.21)			
Bank credit					0.89276***		
					(−2.75)		
Banking reform						0.57957***	
						(−9.74)	
Comprehensive FD index							0.91712***
							(−6.32)
Legal form (default category: other legal forms)							
Joint-stock company	0.49900***	0.57698***	0.53048***	0.56269***	0.55749***	0.50954***	0.53516***
	(−12.54)	(-10.90)	(−12.34)	(−11.14)	(−11.28)	(−12.83)	(−12.09)
Limited liability company	0.42303***	0.44412***	0.43346***	0.43888***	0.43652***	0.42297***	0.43074***
	(−17.20)	(−18.33)	(−18.87)	(−18.47)	(−18.55)	(−19.20)	(−18.92)
Corporate ownership and governance							
Foreign ownership	0.71341***	0.82484***	0.76720***	0.81111***	0.80671***	0.73701***	0.77776***
	(−5.82)	(−3.48)	(−4.75)	(−3.76)	(−3.85)	(−5.42)	(−4.50)
State ownership	0.76115**	0.57533***	0.66021***	0.58356***	0.58775***	0.68778***	0.62419***
	(−2.12)	(−4.30)	(−3.19)	(−4.18)	(−4.12)	(−2.89)	(−3.63)
Number of board directors	0.84171***	0.82122***	0.85046***	0.82872***	0.83065***	0.86174***	0.84492***
	(−8.94)	(−10.99)	(−9.18)	(−10.33)	(−10.23)	(−8.44)	(−9.44)
Number of board directors_squared	1.00499***	1.00559***	1.00489***	1.00544***	1.00540***	1.00468***	1.00509***
	(5.61)	(6.64)	(5.63)	(6.39)	(6.34)	(5.28)	(5.87)
Firm performance							
ROA	0.99624***	0.99564***	0.99574***	0.99566***	0.99567***	0.99598***	0.99575***
	(−3.49)	(−4.06)	(−4.04)	(−4.06)	(−4.06)	(−3.80)	(−4.02)
Profit margin	0.99274***	0.99256***	0.99227***	0.99252***	0.99250***	0.99253***	0.99242***
	(−8.41)	(−8.49)	(−8.88)	(−8.54)	(−8.56)	(−8.64)	(−8.68)
Liquidity ratio	1.00524**	1.00693***	1.00585**	1.00669***	1.00661***	1.00568**	1.00613**
	(2.13)	(2.85)	(2.41)	(2.76)	(2.72)	(2.33)	(2.53)
Solvency ratio	0.99578***	0.99580***	0.99632***	0.99592***	0.99597***	0.99603***	0.99614***
	(−8.27)	(−8.56)	(−7.49)	(−8.28)	(−8.16)	(−8.19)	(−7.86)
Linkage with capital market							
Listed	0.39715**	0.39708***	0.39634***	0.38346***	0.38301***	0.36758***	0.37276***
	(−2.34)	(−2.85)	(−2.92)	(−2.97)	(−2.98)	(−3.13)	(−3.08)
Firm size and age							
Firm size	1.02524***	1.00440	1.00562	1.00355	1.00325	1.00915	1.00428
	(2.57)	(0.48)	(0.61)	(0.39)	(0.35)	(0.99)	(0.46)
Firm age	0.96533***	0.95005***	0.95360***	0.95041***	0.95052***	0.95625***	0.95235***
	(−7.42)	(−12.38)	(−11.42)	(−12.38)	(−12.37)	(−10.59)	(−11.87)
Country-level fixed effects	Yes	No	No	No	No	No	No
NACE division-level fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes
N	10392	10392	10392	10392	10392	10392	10392
Log pseudolikelihood	−28857.48	−29034.21	−28987.39	−29031.23	−29029.52	−28976.01	−29010.36
Harrell's C-statistic	0.699	0.681	0.685	0.681	0.681	0.686	0.683
Wald test (χ^2)	58649.04***	1046.55***	1153.96***	1057.35***	1062.61***	1166.52***	1106.56***

Notes: This table contains results from the survival analysis using the Cox proportional hazards model. Table 1 provides detailed definitions and descriptive statistics of the independent variables. Hazard ratios are reported instead of standard regression coefficients. Standard errors are computed using the Huber-White sandwich estimator. *z* statistics are reported in parentheses beneath the hazard ratios. The Wald test examines the null hypothesis that all standard regression coefficients are zero. ***, **, and * denote statistical significance at the 1%, 5%, and 10% levels, respectively.

circumstances, an instrumental variable (IV) method or a two-stage residual inclusion method (2SRI) should be applied (Liu, 2012; Carlin & Solid, 2014). However, as we showed earlier in Subsection 2.1, all independent variables in our analysis can be considered as being pre-determined, which minimizes the endogeneity problem arising from simultaneity between dependent and independent variables (Iwasaki, 2014). In addition, our estimation period covers a relatively long span of nine years. Finally, dependent variable is a discrete (binary) variable as it is observed on a yearly basis. In this respect none of the three conditions voiced by Liu (2012) applies to our analysis.

Table 3
Estimation of the Cox proportional hazards model by country group.

Target country group	All 17 countries	Group I: EU member states	Group I excluding Baltic states	Group II: Russia and Ukraine	Group III: Non-EU Eastern Europe
Model	[1][a]	[2]	[3]	[4]	[5]
Country-level financial development					
Comprehensive FD index	0.91712***	0.92171***	0.91101***	0.83460**	1.02016
	(−6.32)	(−3.95)	(−2.93)	(−2.46)	(1.15)
Legal form (default category: other legal forms)					
Joint-stock company	0.53516***	0.86918	0.85135	0.43060***	1.20459*
	(−12.09)	(−0.96)	(−1.04)	(−14.20)	(1.84)
Limited liability company	0.43074***	0.45855***	0.37847***	0.37981***	0.26581
	(−18.92)	(−6.30)	(−7.19)	(−18.93)	(−0.96)
Corporate ownership and governance					
Foreign ownership	0.77776***	0.98336*	0.85504	0.66939***	0.51341
	(−4.50)	(−1.87)	(−1.54)	(−6.70)	(−0.70)
State ownership	0.62419***	0.78848	0.80975	0.83067***	0.84673***
	(−3.63)	(−1.15)	(−0.94)	(−4.10)	(−9.27)
Number of board directors	0.84492***	0.86344***	0.90653***	0.89147***	1.88650
	(−9.44)	(−4.23)	(−2.91)	(−2.77)	(1.01)
Number of board directors_squared	1.00509***	1.00534***	1.00420***	1.00080	0.90468
	(5.87)	(4.61)	(3.59)	(0.17)	(−1.39)
Firm performance					
ROA	0.99575***	0.99544	0.99552	0.99679***	1.04606
	(−4.02)	(−1.21)	(−1.13)	(−2.86)	(1.29)
Profit margin	0.99242***	0.99582	0.99528	0.99266***	0.97285
	(−8.68)	(−1.24)	(−1.31)	(−8.03)	(−1.51)
Liquidity ratio	1.00613**	1.00855	1.00929	1.00525**	1.07516
	(2.53)	(0.67)	(0.63)	(2.08)	(1.31)
Solvency ratio	0.99614***	0.99442***	0.99474***	0.99550***	1.01173
	(−7.86)	(−3.23)	(−2.87)	(−8.42)	(0.53)
Linkage with capital market					
Listed	0.37276***	1.71967	1.34509	1.04396	0.18324*
	(−3.08)	(1.30)	(0.67)	(0.08)	(−1.77)
Firm size and age					
Firm size	1.00428	0.92574***	0.88943***	1.02425**	1.28447
	(0.46)	(−3.19)	(−4.25)	(2.31)	(1.60)
Firm age	0.95235***	0.96866***	0.95988***	0.95923***	0.83879
	(−11.87)	(−3.50)	(−3.67)	(−8.24)	(−1.27)
NACE division-level fixed effects	Yes	Yes	Yes	Yes	Yes
N	10392	2532	2258	7764	133
Log pseudolikelihood	−28803.07	−2985.31	−2419.37	−24665.58	−40.40
Harrell's C-statistic	0.703	0.684	0.704	0.663	0.531
Wald test (χ^2)	1723.58***	157.66***	161.94***	915.81***	1198.84***

Notes: This table contains results from the survival analysis using the Cox proportional hazards model. Table 1 provides detailed definitions and descriptive statistics of the independent variables. Hazard ratios are reported instead of standard regression coefficients. Standard errors are computed using the Huber-White sandwich estimator. *z* statistics are reported in parentheses beneath the hazard ratios. The Wald test examines the null hypothesis that all standard regression coefficients are zero. ***, **, and * denote statistical significance at the 1%, 5%, and 10% levels, respectively.
[a] Model [7] in Table 2.

3. Results

The number of failed banks during the analyzed period is captured in Fig. 1. The dynamics of exit rates and Nelson-Aalen estimates of the cumulative hazard functions are somewhat different in the three groups. In Group I (EU members) the exit rate increases in oscillatory pattern but declines after 2013. In the Group II (Russia and Ukraine) the exit rate steadily climbs and slows down after 2012. In both Groups I and II the initial wave of failures occurs shortly after the onset of the global financial crisis. In the Group III (Non-EU Eastern Europe) the failures are relatively stable but the exit rate dramatically increases in 2015. Hence the speed of failure differs in all three groups and it is fastest in Russia/Ukraine (Group II). These differences further motivate our strategy to first estimate our baseline model for the three distinct country groups.

3.1. Baseline and country-groups based estimation

Our baseline estimation results of the Cox proportional hazards model are presented in Table 2. Recall that a (statistically significant estimate of) hazard ratio denotes percentage change in survival probability by one unit change of a covariate in question. The overall results for the whole set of 17 countries show that (i) level of the financial development (proxied by the CDF index) is associated with improved survival probability (column 7), and (ii) majority of the determinants used in the estimation exhibit hypothesized effects with respect to bank survival. The exceptions are insignificant coefficients, and inhibiting factors of firm size (measured with total assets; column 1) and liquidity ratio. The plausible explanation is that larger banks take for granted that they will be bailed out (namely, "too big to fail" moral hazard) and so they take more risk (Kaufman, 2014). In case of the liquidity ratio, the effect does not support survival; however, its economic effect is very marginal and indirectly correlates with Cole and Gunther (1995) who do not find evidence that measures of bank liquidity are associated with predictions of the time to bank failure.

Further, we inspect the impact of individual measures of financial development on bank survival. Results in Table 2 show that the level of banking reform (column 6) exhibits the strongest effect among the financial development indicators. Other alternative financial development measures (liquid liabilities, private credit, bank credit; columns 3–5) are somewhat less economically significant but can also be decisively considered as preventive factors lowering the probability of a bank's exit. The results are in broad accord with those from developed as well as emerging countries that show complementary importance of aggregate measures of financial and banking sector development with respect of bank survival (e.g. Cebula, 2010; DeYoung, 2003; Lin & Yang, 2016).

In the next step, the estimation results based on country-groups are presented in Table 3. Coefficients associated with the comprehensive financial development (CDF index) indicate, in an aggregate form, the sizable positive impact of the financial development with respect to bank survival in three country groups. Specifically, the coefficients associated with the financial development index are less than 1 for EU members and Russia/Ukraine groups (columns 2–4); coefficient is statistically insignificant for remaining countries (column 5), though. The effect of the CDF index contributing to survival probability is found to be stronger for Russia/Ukraine when compared with the EU members. Based on our data and other evidence, Russia and Ukraine exhibit less advanced level of banking reforms and financial development than EU members (Bonin et al., 2015; Fan et al., 2011).

We relate these two observations with the fundamental principle of decreasing marginal returns (Smith, 1950) based on which we also hypothesize that in countries with higher financial development, the contribution of the more advanced banking sector environment to bank survival should be smaller than in countries with lower financial development. In this sense, estimation results, at least indirectly, indicate the presence of diminishing returns from improvement in country-level financial and banking sector development. The result carries a strong implication: since the effect of financial development on bank survival visibly changes with its level, the effort to advance banking sector reforms brings more fruit to financially less developed economies than to developed ones.

In terms of the economic effect of various covariates, the corporate legal form of banks exhibits country-group differences. While joint-stock company exhibits statistically insignificant effect in the EU members (column 2), it is economically significant survival-enhancing factor in Russia/Ukraine group (column 4), while its impact is opposite for non-EU countries (column 5). In Russia and Ukraine, most large-scale banks are operating as joint-stock companies as a consequence of mass privatization, in which transformation of state banks into joint-stock companies was carried out as an important step to distribute their properties to citizens. The significant and positive impact of the variable may reflect this historical preconditions in these countries. Limited liability, on the other hand, exhibits exit-preventing impact consistently across all groups, albeit with statistically insignificant result for non-EU group. The finding resonates well with the fact that in case of this particular legal form the burden to deal with losses is upper-limited by the law. Between the two key legal forms, the limited liability correlates consistently with better survival chances than does the joint stock company.

Ownership structure exhibits comparable influence as preventive factor. Specifically, foreign ownership seems to be important factor behind higher bank survival in Russia/Ukraine (column 4) and EU countries (column 2). It is to be noted that the impact of foreign ownership is also important in Baltic countries as the statistical significance disappears when they are eliminated from the EU group (column 3). In fact, the estimation of the foreign ownership variable limited to observations in the Baltic states demonstrated that the survival probability of foreign-owned banks is 27.4% higher in these countries, *ceteris paribus*, indicating that the presence of foreign investors in ownership greatly enhanced risk management in the Baltic banks.[13] In non-EU countries, the effect of foreign ownership lacks statistical significance. Further, state ownership is linked with improved survival probability and exhibits very similar economic impact in both Russia/Ukraine and non-EU groups (columns 4 and 5), while statistically insignificant impact is found for EU countries (column 2 and 3). The exit-preventive effect of the state in both groups might be due to desire of the state to retain control over even imperfectly functioning financial institutions. Various reasons for such behavior are evidenced in the economic transformation literature related specifically to the countries under research. For example, soft budget constraints can be practiced between state-controlled credit providers (banks) and firms because they may be hidden by multi-level ownership links among firms and financial institutions under state control (Hanousek & Kočenda, 2008; Kočenda, 1999). Further, preferential treatment of state-controlled firms by state-controlled financial intuitions constitutes the emergence of a subsidy, whose effects in firms in Central Europe were shown already in Frydman et al. (2000). Specifically, in Russia Chernykh (2008) provides evidence for a dramatically high level (37–48%) of state control over the sampled firms. In this sense. the finding also reflects less state involvement in the banking system of the EU members (Bonin et al., 2015; Hanousek et al., 2007) when compared to other two groups.

As for the corporate governance, larger boards of directors decrease the probability of bank failure quite significantly in EU members and Russia/Ukraine (columns 2–4). However, the squared term of the number of board directors is slightly over 1, meaning that the non-linear effect of the board size is negative. This means that, for statistically significant impacts we show that the relationship between the board size and probability of bank survival follows an inverted U-shape. Hence, the probability of exit for banks with larger boards is relatively low, but it increases as the board grows excessively large; statistical insignificance prevents conclusions for the non-EU countries, though. Our results are in line with De Andres and Vallelado (2008) who document an inverted U-shaped relation between board size and performance on a sample of 69 large commercial banks from six developed countries (during 1995–2005).

[13] The estimation results are available upon request.

Bank performance measures indicate a correlation with better chances for survival. However, the economic significance of the ROA and profit margin is rather low as both coefficients are close to the benchmark of one. Moreover, the effect is statistically significant for Russia/Ukraine (column 4), but not for other country groups. Negligible negative impact is produced by the liquidity ratio whose coefficients are essentially close to one and statistically insignificant, with the exception of Russia/Ukraine (column 4). Solvency ratio produces statistically significant survival-contributing effect in most countries with exception of the non-EU group, however its economic impact is negligible.

The factor representing bank being listed on a stock exchange exhibits a substantial economic impact only in non-EU countries; rest of coefficients is statistically insignificant. It is worth mentioning that stock markets in the CEE region were established primarily as vehicles connected to mass privatization schemes and thus, in early 2000's they still substantially differed from the mature Western stock markets in terms of capitalization, information processing etc. (Hanousek et al., 2009). Still to be listed on a local stock exchange, a bank has to comply with numerous criteria that are also linked to its performance, quality, and compliance with rules imposed by a regulator – as such, listed banks are likely to exhibit more resilience towards exist. Our findings is in line with earlier results of Männasoo and Mayes (2009) who show that Eastern European listed banks are strongly and statistically significantly less caught by distress because of their strength, and because their disclosure requirements make them subject to market discipline. Further, many banks in non-EU countries are also part of financial groups with EU banks so they would have better control mechanisms.

Bank specific characteristics show that size is economically a small risk factor for bank survival in Russia/Ukraine (column 4), but it is rather exit-preventive factor in the EU group (columns 2–3); result is statistically insignificant for non-EU countries. In general, firm size is usually considered to be a preventive factor (e.g., Gersoki, 1995), which intuitively is straightforward, as it is expected that larger firms have lower hazard rates of exiting than smaller firms. Nevertheless, banks in the CEE and FSU regions are still quite distinct from those of developed countries (Brůha & Kočenda, 2018) and higher proportion of the lower-quality assets in the Russian and Ukrainian banks might be a reasonable explanation behind the findings. A bank's age, on other hand, can be regarded as mildly preventive factor in the EU group (columns 2–3) and Russia/Ukraine (column 4); result is statistically insignificant for non-EU countries. The finding is intuitive as the older financial institutions can be regarded as more stable, provided that they exhibit a sound standing.

Table 4

Estimation of the Cox proportional hazards model by the level of solvency ratio and ROA.

Target financial institutions	High solvency and high ROA	High solvency and low ROA	Low solvency and high ROA	Low solvency and low ROA
Model	[1]	[2]	[3]	[4]
Country-level financial development				
Comprehensive FD index	0.96143**	0.88782***	0.90493***	0.88186***
	(−2.37)	(−3.54)	(−3.90)	(−4.95)
Legal form (default category: other legal forms)				
Joint-stock company	0.74152***	0.61172***	0.50261***	0.44250***
	(−2.61)	(−4.33)	(−6.15)	(−8.75)
Limited liability company	0.50777***	0.40666***	0.40567***	0.46466***
	(−6.56)	(−8.40)	(−9.58)	(−10.16)
Corporate ownership and governance				
Foreign ownership	0.84360	0.74706***	0.65371***	0.75769**
	(−1.21)	(−3.35)	(−2.83)	(−2.37)
State ownership	1.53722*	0.64621	0.32653***	0.58859***
	(1.93)	(−1.19)	(−3.28)	(−2.61)
Number of board directors	0.87647***	0.87852**	0.78441***	0.86469***
	(−4.36)	(−2.00)	(−5.73)	(−3.37)
Number of board directors_squared	1.00396***	0.99487	1.01064***	1.00601**
	(3.45)	(−0.64)	(8.38)	(2.38)
Firm performance				
Profit margin	0.99151***	0.99292***	0.98605***	0.99511***
	(−2.86)	(−5.54)	(−4.46)	(−3.33)
Liquidity ratio	1.01133***	1.00356	0.99856	0.99417
	(3.26)	(0.85)	(−0.16)	(−0.81)
Linkage with capital market				
Listed	0.44337*	0.83864**	0.62793	0.82508
	(−1.85)	(−2.45)	(−0.66)	(−0.33)
Firm size and age				
Firm size	0.96161	1.00336	1.02732	0.98083
	(−1.51)	(0.16)	(1.25)	(−1.23)
Firm age	0.97281***	0.92733***	0.95407***	0.97258***
	(−2.64)	(−11.60)	(−5.67)	(−3.09)
NACE division-level fixed effects	Yes	Yes	Yes	Yes
N	2799	2334	2681	2578
Log pseudolikelihood	−4608.02	−5727.74	−6120.55	−8067.52
Harrell's C-statistic	0.629	0.726	0.654	0.643
Wald test (χ^2)	105.90***	358.49***	561.53***	227.00***

Notes: This table contains results from the survival analysis using the Cox proportional hazards model. Table 1 provides detailed definitions and descriptive statistics of the independent variables. Hazard ratios are reported instead of standard regression coefficients. Standard errors are computed using the Huber-White sandwich estimator. z statistics are reported in parentheses beneath the hazard ratios. The Wald test examines the null hypothesis that all standard regression coefficients are zero. ***, **, and * denote statistical significance at the 1%, 5%, and 10% levels, respectively.

Table 5
Estimation of Cox proportional hazards model in different periods.

Estimation period	2007–2008	2007–2010	2007–2013	2009–2010	2011–2013	2014–2015
Model	[1]	[2]	[3]	[4][a]	[5][a]	[6][a]
Country-level financial development						
Comprehensive FD index	1.25029***	1.14222***	0.97247**	1.10028***	0.85482***	0.81008***
	(6.28)	(6.49)	(−2.33)	(3.76)	(−6.71)	(−8.17)
Legal form (default category: other legal forms)						
Joint-stock company	0.51054***	0.42238***	0.46153***	0.39366***	0.47526***	0.73691***
	(−3.06)	(−7.65)	(−12.02)	(−7.12)	(−9.28)	(−3.33)
Limited liability company	0.37181***	0.37836***	0.38036***	0.38234***	0.38224***	0.58825***
	(−6.20)	(−11.82)	(−18.35)	(−9.96)	(−14.06)	(−6.49)
Corporate ownership and governance						
Foreign ownership	0.40811	0.48673**	0.62717***	0.52062*	0.72383*	0.64684**
	(−1.50)	(−2.43)	(−2.92)	(−1.92)	(−1.72)	(−2.04)
State ownership	0.67100*	0.98874	0.76047***	1.11681	0.64414***	0.85566
	(−1.76)	(−0.11)	(−4.03)	(0.95)	(−4.98)	(−1.61)
Number of board directors	0.67711***	0.68522***	0.79521***	0.68975***	0.89943*	0.92796***
	(−4.34)	(−8.53)	(−9.73)	(−7.54)	(−1.86)	(−2.85)
Number of board directors_squared	1.01095***	1.01052***	1.00660***	1.01017***	0.99859	1.00215
	(5.12)	(8.81)	(6.98)	(7.70)	(−0.21)	(1.32)
Firm performance						
ROA	0.99506	0.99389***	0.99504***	0.99359***	0.99563**	0.99715
	(−1.20)	(−3.11)	(−3.84)	(−2.90)	(−2.55)	(−1.54)
Profit margin	0.99096***	0.99173***	0.99347***	0.99203***	0.99451***	0.99049***
	(−2.69)	(−4.79)	(−6.14)	(−4.06)	(−4.33)	(−5.89)
Liquidity ratio	1.00322	1.01450***	1.00719**	1.01738***	1.00175	1.00368
	(0.34)	(3.73)	(2.51)	(4.13)	(0.45)	(0.84)
Solvency ratio	0.99944	0.99623***	0.99588***	0.99519***	0.99581***	0.99664***
	(−0.30)	(−4.00)	(−6.93)	(−4.40)	(−5.57)	(−3.97)
Linkage with capital market						
Listed	0.22535***	0.12279***	0.41060**	0.19776***	0.56303	0.32551**
	(−9.77)	(−7.97)	(−2.18)	(−8.13)	(−1.42)	(−2.23)
Firm size and age						
Firm size	1.01588	0.97662	1.01059	0.96253*	1.03514**	0.99697
	(0.46)	(−1.36)	(0.94)	(−1.89)	(2.39)	(−0.19)
Firm age	0.95820***	0.95979***	0.95492***	0.96024***	0.95254***	0.94803***
	(−3.25)	(−5.88)	(−9.95)	(−4.93)	(−7.88)	(−6.39)
NACE division-level fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
N	10392	10392	10392	10166	9544	8215
Log pseudolikelihood	−2011.75	−7561.35	−19471.39	−5537.15	−11841.09	−9487.34
Harrell's C-statistic	0.723	0.716	0.690	0.717	0.689	0.691
Wald test (χ^2)	52321.23***	86570.05***	883.86***	63443.37***	507.14***	304.65***

Notes: This table contains results from the survival analysis using the Cox proportional hazards model. Table 1 provides detailed definitions and descriptive statistics of the independent variables. Hazard ratios are reported instead of standard regression coefficients. Standard errors are computed using the Huber-White sandwich estimator. z statistics are reported in parentheses beneath the hazard ratios. The Wald test examines the null hypothesis that all standard regression coefficients are zero. ***, **, and * denote statistical significance at the 1%, 5%, and 10% levels, respectively.
[a] Estimation results without the observations of firms failed before the indicated period.

3.2. Estimation based on criteria of bank soundness

Country groups introduced in previous section distinguish among banks depending on differences in quality of the banking sectors evidenced for the European countries (Brůha & Kočenda, 2018). However, such division does not necessarily allow assessment based on economic standing of individual banks. In the next step we provide an alternative point of assessment: we divide banks into four groups according to their financial soundness evaluated by the subset of the CAMELS criteria.

We proceed in the following way. Initially, we perform a principle component analysis (PCA) to capture potential structure behind the bank soundness in terms of the available CAMELS factors. The results of the PCA are provided in Panel b of the Appendix Table A2. Solvency ratio possesses the highest eigenvector (0.7359) followed by the ROA (0.6382) in the first component.[14] Furthermore, the first component explains about 62.3 percent of total variance among the factors. We are aware that the new variables (the components) do not have the same interpretation as the original CAMELS factors. However, they might show some resemblance and for that we form groups of banks based on solvency and ROA, factors with the highest eigenvalues. First, we create two groups to distinguish between highly sound banks (high solvency and high ROA) and poorly sound banks (low solvency and low ROA). Further, we create two

[14] The outcome of the PCA is indirectly in line with the recent finding of Carmona et al. (2019) who show, on a sample of the U.S. banks, that higher values for (pretax) return on assets, and (total risk-based) capital ratio are associated with higher chances of bank survival.

intermediate groups of banks performing well in only one of the two criteria (high solvency and low ROA; low solvency and high ROA). With the above formed groups we perform new round of estimation and present the results in Table 3. In order to avoid any unwanted impact, we estimate our specification without the solvency and ROA factors.[15]

The level of the comprehensive financial development index is decisively contributive factor with respect to bank survival. Moreover, the effect is economically stronger for banks with low ROA (and either high or low solvency) with coefficients being less than 0.9, when compared to two groups of banks with high ROA where the coefficients are above 0.9. The result indicates that for banks with lower asset quality (proxied by ROA) the general progress in financial development might partially work as a safeguard against their failure. A side effect of such result might be a potential preservation of less competent banks operating in, and possibly also due to, otherwise improved banking environment.

Further results show that both types of legal form can be regarded as exit-preventive factors, with limited liability showing slightly stronger impact. Both legal form further differ with respect to the soundness of a bank as joint-stock legal form exhibits marginally greater impact on banks with low solvency and low ROA since the coefficient is lower than that of the limited liability. On the other hand, limited liability legal form exhibits greater impact on other groups of banks, i.e. banks in the middle of soundness or well performing ones. Overall, limited liability legal form is associated with better survival chances of best or fairly performing banks, while joint-stock legal form improves survival chances of the banks with poor soundness.

Ownership structures play a positive and economically significant role in strengthening the probability of bank survival. Foreign ownership is shown to be preventive factor specifically for weaker banks (with low solvency or low ROA); the finding is indirectly linked to the evidence brought by Grittersová (2014) who shows how good reputation from solid foreign banks helps to affect financial strength in host countries. In contrast, foreign owners seem to have a somewhat smaller effect on the fittest banks (in terms of asset quality (ROA) and solvency), but statistically insignificant coefficient precludes any firm inference. Further, state ownership is also shown to be preventive factor in case of the weakest banks (measured by the lowest solvency ratio) and it impact economically surpasses the effect of the foreign ownership. On the other hand, state ownership is linked with increased probability of exit in case of the strong banks. In fact, according to column 2 in Table 4, the good-performing state-owned banks in 2006 faced with 53.7% higher risk of management failure during the subsequence period, if other conditions are held constant. We conjecture that the weak monitoring by the state authorities might lead these "good" banks to slack of top management.

Effect of the corporate governance (proxied by the board of directors' size) shows that larger boards of directors decrease the probability of bank failure but the impact is non-linear; statistical insignificance precludes assessment for the bank group high solvency and low ROA. The non-linear effect of the board size is negative as the squared term of the number of board directors is slightly over 1. Hence, the link between the board size and bank survival chance is captured in an inverted U-shaped pattern: i.e., the banks benefit from larger boards but the probability of bank failure increases as the board gets excessively large. The result correlates with hypothesis linking advantages of monitoring and advising with board size, and it also corresponds well with the related outcome of De Andres and Vallelado (2008) who, in a sample of large international commercial banks, find an inverted U-shaped relation between bank performance and board size.

Banks with high solvency improve their survival chances from being listed on a stock exchange; coefficients are statistically insignificant for low solvency banks. This is especially important in case of banks with low ROA who benefit from the stock-market-status despite of potentially lower quality of their assets. Still, for banks to be listed, a compliance with regulator-imposed criteria is a strict condition and listed banks are likely to have better survival chances. The finding is in line with earlier results of Männasoo and Mayes (2009) who show that listed banks in Eastern European economies are quite resilient to distress, benefiting from disclosure requirements and market discipline.

The rest of the factors we tested exhibit mostly only marginal effects since associated coefficients are close to one - small failure-preventing effect is associated with profit margin, and firm age. Statistical insignificance of firm size coefficients precludes more detailed evaluation, similarly as in case of liquidity ratio being preventive factor for low solvency banks while minir decreasing survival chances are associated with high solvency banks.

In addition to the detailed and factor-specific results discussed above, an interesting pattern emerges from the aggregation of the above findings. The largest economic impact of the legal form, ownership and governance factors concentrates in two bank groups with low solvency, relative to other two groups with high solvency; the pattern is based on statistically significant coefficients. On the other hand, the economic impact of the legal form, ownership and governance factors is smallest in bank group with best soundness (high solvency/high ROA). The key take from this result is that in terms of the bank soundness, the banks with low solvency benefit most as the specific determinants exhibit most contributive effects towards their survival. Our explanation of this pattern is based on the central principle of decreasing marginal returns (Smith, 1950): for banks with a high status (high solvency), the contribution of the above factors should be lower than for banks in lower-rank groups (low solvency).

3.3. Dynamics of banking reform and survival

We estimated the Cox proportional hazards model for different periods for which we also adjusted the number of analyzed (failed and survived) banks. The results are reported in Table 5 and show that the progress in financial development varies in its impact with overall economic development. Results appear to indicate that it makes exit more likely during the GFC and shortly afterwards (2007–2010). The effect is strongest at the beginning of the crisis (2007–2008) and is in line with the overall negative impact of the GFC on banks documented in the literature (Claessens & Van Horen, 2015). Results also show that exit is more likely during the initial stage of the European sovereign debt crisis that began to unfold at the end of 2009 and intensified in 2010 (2009–2010). Otherwise, the

[15] Estimation results with both factors (solvency and ROA) included do not materially differ; not reported but available upon request.

overall financial development improves survival chances during the rest of the research period and its effect is stronger as the GFC becomes more distant in time. More importantly, progress in financial development contributes substantially to bank survival probability during (2011–2013) and after the worst stages of the European sovereign debt crisis (2014–2015) the survival chances even marginally improve. The findings are also in line with the empirical evidence showing negative impact of the European sovereign debt crisis on European banks' equity returns (Allegret et al., 2017), on their assets via holding of sovereign debt (Gennaioli, Martin, & Rossi, 2018), and links between sovereign risk and European banking sector quality at large (Brůha & Kočenda, 2018). The effect of the firm-specific controls is largely time-invariant and corresponds to the effects reported earlier.

3.4. Robustness checks

In order to verify the validity of our results, we performed various robustness checks. First, we re-estimated the model to control for differences in bank size and age based on the median values. When we differentiate between size (age) we do not include size (age) in estimated specification. In Table A.3 we report results for four groups of banks: larger/smaller and older/younger banks; the criterion for dividing the sample into high/low values is above or below the median for the respective variables. The results show that the overall development of banking sector is beneficial for individual banks in a country. Positive impact of the CFD index is marginally better for smaller and younger banks than for their larger and older counterparts. In general, the effect of bank characteristics does not greatly vary across larger/smaller and older/younger banks, though. The assessment based on statistically significant coefficients also shows that results are also similar to those of the baseline model reported in Table 2. We conclude that our results are robust with respect to size and age.

Finally, we re-estimated alternative hazards models with different assumptions on survival distribution. These include the exponential, Weibull, and Gompertz distributions. The results presented in Table A.4 show that effects of the CFD index and bank-specific controls are invariant with respect to assumptions of survival distribution. The survival-associated effects also corresponds to those reported earlier.

4. Concluding remarks

Commercial banking sectors in CEE countries developed as part of the economic transformation during the 1990's and did not reach sufficient level of maturity until well into 2000's when the financial crisis swept the global financial markets. Since healthy banking sector is a prerequisite for economic development in any country, knowledge of the bank survival determinants in CEE markets represents valuable information for industry and policy makers. We analyze bank survival on large dataset covering 17 CEE markets during the period from 2007 to 2015 by estimating the Cox proportional hazards model. We analyze banks across country groups and also sort banks according to their soundness and profitability.

Our results show that progress in banking sector reforms and financial development in general positively affect bank survival probabilities. Results also appear to indicate that it makes exit more likely during the GFC, shortly afterwards, and during the initial stage of the European sovereign debt crisis. Otherwise, the overall financial development improves survival probabilities during the rest of the research period and its effect is stronger as the GFC becomes more distant in time and after the worst stages of the European sovereign debt crisis. We also show that effects of survival determinants (legal form, ownership and governance factors) are economically more significant for banks that exhibit low level of solvency and less economically significant for the best performing banks. The pattern indicates the existence of the diminishing marginal returns of the bank characteristics on their survival rate that is linked to bank soundness.

Financial indicators are helpful factors to assess bank survival rate and they exhibit intuitively expected impact. However, their effect, in terms of economic significance, is smaller in comparison to other factors; this is a difference from the impact found in developed markets. Specifically, ownership structure and legal form are the key economically significant factors that exhibit strongest economic effect in explaining bank survival rates. Further, we also document the existence of the inverted U-shape link with respect to the board size. Finally, we performed several robustness checks to show consistency of our results with respect to size, age, and alternative assumptions on survival distribution.

The above results offer direct policy implications for CEE countries to further cultivate institutional environment related to banking sector quality and financial development. Such improvements are needed because we show that despite that progress in financial development is linked to improved bank survival probabilities, bank exits are more likely during periods of distress. This result is critical for central banks due to their regulatory and governance mandate. Further, since economic impact of specific determinants on survival rates is smallest for best performing banks, our findings are most relevant as early warning system indicators for low-performing banks that are well represented in our sample but often overlooked.

Acknowledgement

We are grateful for helpful comments from John Bonin, Carl Chen (Editor), Martin Geiger, Svatopluk Kapounek, Roman Matoušek, Steven Ongena, Vasilis Pappas, Petr Teplý, and two anonymous referees. Kočenda acknowledges support from the Grant Agency of the Czech Republic (No. 19-22488S). Iwasaki acknowledges financial support from the Japan Securities Scholarship Foundation (JSSF), the Nomura Foundation, and the Mitsubishi Foundation. The usual disclaimer applies.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.iref.2020.06.020.

Table A.1
Correlation matrix of variables used in the empirical analysis

Variable No.	Variable name	Correlation matrix																	
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1	Liquid liabilities	1.000																	
2	Private credit	0.616	1.000																
3	Bank credit	0.644	0.998	1.000															
4	Banking reform	0.899	0.748	0.770	1.000														
5	Comprehensive FD index	0.859	0.924	0.937	0.933	1.000													
6	Joint-stock company	−0.115	−0.102	−0.113	−0.124	−0.124	1.000												
7	Limited liability company	0.024	−0.004	−0.015	−0.006	−0.001	−0.475	1.000											
8	Foreign ownership	0.164	0.097	0.105	0.167	0.145	−0.028	0.022	1.000										
9	State ownership	−0.080	−0.046	−0.044	−0.120	−0.079	−0.049	−0.253	−0.081	1.000									
10	Number of board directors	0.214	0.220	0.223	0.258	0.250	0.185	−0.215	0.176	0.026	1.000								
11	Number of board directors_squared	0.092	0.120	0.120	0.126	0.126	0.090	−0.110	0.112	0.003	0.776	1.000							
12	ROA	−0.034	−0.019	−0.022	−0.012	−0.023	0.037	0.118	−0.022	−0.077	−0.014	−0.011	1.000						
13	Profit margin	−0.019	0.008	0.003	0.016	0.003	0.060	0.069	0.040	−0.098	0.092	0.073	0.539	1.000					
14	Liquidity ratio	−0.045	−0.036	−0.038	−0.056	−0.048	0.056	0.029	0.015	−0.043	−0.011	−0.002	0.072	0.118	1.000				
15	Solvency ratio	0.080	0.056	0.071	0.064	0.074	0.025	−0.252	−0.085	0.186	0.010	−0.013	0.203	0.107	0.202	1.000			
16	Listed	−0.002	−0.030	−0.019	−0.036	−0.024	0.073	−0.109	0.095	−0.024	0.181	0.101	−0.028	0.060	0.018	−0.002	1.000		
17	Firm size	0.130	0.055	0.061	0.164	0.112	−0.002	−0.213	0.210	0.142	0.259	0.206	−0.175	0.075	0.015	0.066	0.113	1.000	
18	Firm age	0.182	0.098	0.109	0.248	0.174	0.023	−0.230	0.022	0.006	0.213	0.106	−0.030	0.046	−0.029	0.166	0.168	0.250	1.000

Source: For definitions and descriptive statistics of the variables, see Table 1.

Table A.2
Estimation results of principal component analysis

Panel A: Results of country-level financial variables

Eigenvalue of the correlation matrix			Eigenvectors of the first component	
Component no.	Eigenvalue	Cumulative percentage of total variance	Variables	Eigenvector
1	3.3409	0.835	Liquid liabilities	0.4701
2	0.5763	0.979	Private credit	0.5054
3	0.0815	1.000	Bank credit	0.5127
4	0.0013	1.000	Banking reform	0.5106

Panel B: Results of firm-level financial performance variables

Eigenvalue of the correlation matrix			Eigenvectors of the first component	
Component no.	Eigenvalue	Cumulative percentage of total variance	Variables	Eigenvector
1	1.6921	0.623	Solvency ratio	0.7359
2	1.0810	0.733	ROA	0.6382
3	0.7996	0.893	Profit margin	0.6144
4	0.4273	1.000	Liquidity	0.2718

Source: For definitions and descriptive statistics of the variables, see Table 1.

Table A.3
Estimation of the Cox proportional hazards model by firm size and age

Target financial institutions	Larger financial institutions	Smaller financial institutions	Older financial institutions	Younger financial institutions
Model	[1]	[2]	[3]	[4]
Country-level financial development				
Comprehensive FD index	0.90660***	0.87080***	0.94020***	0.89174***
	(−4.84)	(−3.77)	(−2.98)	(−6.01)
Legal form (default category: other legal forms)				
Joint-stock company	0.57957***	0.53306***	0.61252***	0.50346***
	(−7.16)	(−8.63)	(−6.87)	(−9.00)
Limited liability company	0.49093***	0.41274***	0.42481***	0.45551***
	(−10.02)	(−15.06)	(−11.86)	(−13.83)
Corporate ownership and governance				
Foreign ownership	0.61394***	0.61411*	0.92415	0.52601***
	(−3.26)	(−1.88)	(−0.40)	(−3.81)
State ownership	0.74052***	0.77898***	0.96986	0.67705***
	(−4.08)	(−2.90)	(−0.40)	(−4.76)
Number of board directors	0.84177***	0.82872***	0.78084***	0.88140***
	(−7.33)	(−3.64)	(−10.68)	(−4.57)
Number of board directors_squared	1.00523***	1.00805	1.01028***	1.00358***
	(5.58)	(1.45)	(11.18)	(3.40)
Firm performance				
ROA	0.99257***	0.99826	0.99536***	0.99592***
	(−3.14)	(−1.28)	(−2.73)	(−2.92)
Profit margin	0.99388***	0.98998***	0.99097***	0.99335***
	(−5.73)	(−5.69)	(−6.16)	(−5.95)
Liquidity ratio	0.99864	1.01239***	1.01487***	1.00096
	(−0.34)	(4.37)	(4.44)	(0.29)
Solvency ratio	0.99882	0.99379***	0.99380***	0.99744***
	(−1.56)	(−9.37)	(−8.61)	(−3.95)
Linkage with capital market				
Listed	0.73480	0.21546***	0.28026***	0.68882
	(−0.78)	(−3.00)	(−3.29)	(−0.65)
Firm size and age				
Firm size			0.95985***	1.01476
			(−2.92)	(1.21)
Firm age	0.94571***	0.96292***		
	(−9.75)	(−6.29)		
NACE division-level fixed effects	Yes	Yes	Yes	Yes
N	4986	5406	5496	4896
Log pseudolikelihood	−12818.26	−13914.84	−11091.36	−15729.30

(continued on next page)

Table A.3 (*continued*)

Target financial institutions	Larger financial institutions	Smaller financial institutions	Older financial institutions	Younger financial institutions
Model	[1]	[2]	[3]	[4]
Harrell's C-statistic	0.690	0.683	0.681	0.631
Wald test (χ^2)	503.59***	648.43***	586.48***	440.08 ***

Notes: This table contains results from the survival analysis using the Cox proportional hazards model. Estimation of Model [2]/[3] is performed based on total assets above/below mediam value (7.490). Estimation of Model [4]/[5] is performed based on firm age above/below mediam value (9 years). Table 1 provides detailed definitions and descriptive statistics of the independent variables. Hazard ratios are reported instead of standard regression coefficients. Standard errors are computed using the Huber-White sandwich estimator. *z* statistics are reported in parentheses beneath the hazard ratios. The Wald test examines the null hypothesis that all standard regression coefficients are zero. ***, **, and * denote statistical significance at the 1%, 5%, and 10% levels, respectively.

Table A.4

Estimation of parametric survival model with different distributions

Covariates/Assumption of survival distribution	Exponential	Weibull	Gompertz
Model	[1]	[3]	[3]
Country-level financial development			
Comprehensive FD index	0.91861***	0.90963***	0.90865***
	(−6.47)	(−6.67)	(−6.75)
Legal form (default category: other legal forms)			
Joint-stock company	0.56500***	0.51736***	0.51975***
	(−11.59)	(−12.12)	(−12.05)
Limited liability company	0.45914***	0.41353***	0.41581***
	(−18.69)	(−18.83)	(−18.79)
Corporate ownership and governance			
Foreign ownership	0.80146***	0.76067***	0.76182***
	(−4.19)	(−4.65)	(−4.64)
State ownership	0.63812***	0.61028***	0.61117***
	(−3.54)	(−3.68)	(−3.67)
Number of board directors	0.85101***	0.84261***	0.84346***
	(−9.26)	(−9.37)	(−9.34)
Number of board directors_squared	1.00488***	1.00516***	1.00513***
	(5.75)	(5.90)	(5.88)
Firm performance			
ROA	0.99613***	0.99548***	0.99552***
	(−3.90)	(−4.02)	(−4.00)
Profit margin	0.99271***	0.99200***	0.99199***
	(−8.87)	(−8.65)	(−8.67)
Liquidity ratio	1.00572**	1.00613**	1.00606**
	(2.47)	(2.40)	(2.38)
Solvency ratio	0.99638***	0.99597***	0.99599***
	(−7.92)	(−7.80)	(−7.81)
Linkage with capital market			
Listed	0.37983***	0.36144***	0.36122***
	(−3.04)	(−3.14)	(−3.14)
Firm size and age			
Firm size	1.00482	1.00497	1.00529
	(0.55)	(0.51)	(0.55)
Firm age	0.95386***	0.95037***	0.95036***
	(−11.85)	(−11.94)	(−11.95)
NACE division-level fixed effects	Yes	Yes	Yes
N	10392	10392	10392
Log pseudolikelihood	−7965.12	−7297.45	−7467.36
Wald test (χ^2)	1162.51***	1075.62***	1079.23***

Notes: This table contains the results from a survival analysis using 3 parametric estimators for a robustness check. Table 1 provides detailed definitions and descriptive statistics of the independent variables. Standard errors are computed using the Huber-White sandwich estimator. *z* statistics are reported in parentheses beneath the regression coefficients. The Wald test examines the null hypothesis that all coefficients are zero. ***, **, and * denote statistical significance at the 1%, 5%, and 10% levels, respectively.

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