Institute for Employment Research

The Research Institute of the Federal Employment Agency

IAB

IAB-Discussion Paper 13/2014

Articles on labour market issues

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Contents

Abstract

This paper introduces a large-scale administrative panel data set on corporate bankruptcy in Germany that allows for an econometric analysis of involuntary exits where previous studies mixed voluntary and involuntary exits. Approximately 83 percent of all bankruptcies occur in plants with no more than 10 employees, and 61 percent of all bankrupt plants are not older than 5 years. The descriptive statistics and regression analysis indicate substantial negative age dependence with respect to bankruptcy risk but confirm negative size dependence for mature plants, only. Our results corroborate hypotheses stressing increasing capabilities and positional advantage, both predicting negative age dependence with respect to bankruptcy risk due to productivity improvements. The results are not consistent with the theories explaining age dependence via imprinting or structural inertia.

Zusammenfassung

Dieses Papier stellt einen neuartigen Panel-Datensatz zu Insolvenzen für Deutschland vor, der es im Gegensatz zu anderen Studien erlaubt, ökonometrische Analysen zu unfreiwilligen Schließungen durchzuführen. Wir finden, dass ca. 83 Prozent aller Insolvenzen in Betrieben mit weniger als 10 Beschäftigten stattfinden und 61 Prozent aller insolventen Betriebe nicht älter als 5 Jahre sind. Unsere Deskriptionen und Regressionen verweisen darauf, dass das Insolvenzrisiko mit dem Betriebsalter geringer wird. Ein negativer Zusammenhang zwischen Betriebsgröße und Insolvenzrisiko lässt sich jedoch nur für ältere Betriebe nachweisen. Unsere Ergebnisse unterstützen Hypothesen, die von Produktivitätsvorteilen älterer Betriebe ausgehen. Sie sind nicht kompatibel mit Hypothesen, die mit dem Alter steigende Risiken erwarten, z.B. aufgrund überholter oder verkrustender betrieblicher Strukturen.

JEL classification: L1, L2

Keywords: bankruptcy, plant exit, organizational mortality

Acknowledgements: The authors thank Daniel Fackler, Claus Schnabel, and Till von Wachter for helpful comments. This study is based on customized data. We therefore thank Cerstin Rauscher, other IAB staff members and staff members of the German Federal Employment Agency's for their indispensable support concerning data provision.

1 Introduction

Many studies analyzing plant closures connote closure with ‘failure’, ‘mortality’, or ‘death’, thereby underlining researchers’ interest in *involuntary* closures due to economic distress or a general lack of economic viability. Studying reasons for involuntary plant closures is important because such closures are typically accompanied by a loss of capital, whether it is the owners’ and creditors’ financial capital or the employees’ firm-specific human capital. We argue that bankruptcies indicate involuntary closures while plant closures, in general, can be voluntary or involuntary. This paper contributes to the literature by utilizing a new large-scale administrative panel data set on corporate bankruptcy in Germany to comprehensively describe involuntary exit.[1] By exclusively using information on bankruptcy, we avoid running the risk of confounding very different reasons for exit. To our knowledge, this is the first paper that describes plant bankruptcy and, thus, involuntary exit in Germany using administrative data. The particular strength of our contribution is the precise and comprehensive administrative information on bankruptcy and other plant characteristics, which enables us to describe economic failure and the role of age and size in great detail.

Analyzing the determinants of organizational failure has a long tradition in industrial economics (Jovanovic 1982), financial economics (Altman 1968), and social sciences (Stinchcombe 1965). Much of the debate centers on age dependence in failure risk and whether size protects against plant failure. Negative age dependence in bankruptcy risk implies a rather stable population of plants, where mature plants are better protected against adverse economic shocks than their younger competitors. In this situation, young firms, typically embodying new ideas, will find it hard to gain ground and technological progress will be primarily generated within older organizations. Conversely, a Schumpeterian explanation of creative destruction (Schumpeter 1942) implies positive age dependence and a fragile population of older firms: older firms become obsolete frequently and are swept away by younger plants that embody technological progress. Larger plants accumulated more ‘organizational capital’ (Levinthal 1991) and should find it easier to buffer adverse shocks. It is typically assumed that size dependence is negative. While there is less dispute about the sign of size dependency, heterogeneous results regarding the sign of age dependency have motivated research analyzing the interdependencies between age and size (Hannan et al. 1998), and we follow this line of inquiry.

After discussing the conceptual differences between voluntary and involuntary plant closure, we discuss theoretical arguments pertaining to the effects of age and size on involuntary exit. We then describe the new bankruptcy data and estimate age and size dependencies in bankruptcy risk.

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[1] Fackler et al. (2012) provide evidence for the reasons for plant closure in Germany. They don’t use bankruptcy information and don’t distinguish between voluntary and involuntary closure.

2 Voluntary versus Involuntary Exit

Although measuring plant closure, most studies discuss their results in the light of plant failure. The underlying assumption seems to be that closing plants would have continued their economic activity if it were economically feasible. Thus, involuntary exit is assumed. If plants close for reasons other than economic distress or insolvency, utilizing plant exit to proxy for plant failure is a misspecification.

Theoretical papers distinguish among different modes of exit (Hudson 1986, Schary 1991). Schary (1991), for instance, distinguishes among voluntary closure, takeover, and bankruptcy. She demonstrates that these modes of exit have different explanations and that the decisions are made by different interest groups. There is also compelling empirical evidence for the notion that a considerable share of establishments close despite having been successful. Bates (2005) analyzes plant closure among small U.S. plants and shows that, after closure, approximately one third of the closed plants were evaluated as successful by their owners. He argues that owners continually compare the expected payoff from continuing business operations with the expected income from alternative forms of employment. Thus, the shutdown of a successful plant is often caused by the existence of more profitable alternatives and not by the failure of the business activity. This line of reasoning is confirmed by Bates' finding that more educated owners (who have better outside options) are more likely to report that the closed business has been successful. Headd (2003) highlights that a number of closed but successful enterprises were founded on a short-term basis, e.g., as a learning opportunity for their founders. Clearly, the closure of a temporary business does not reflect failure. Taylor (1999) reports that many self-employed individuals voluntarily shift to alternative forms of employment, which also implies that their closed businesses cannot be considered plant failures. Van Praag (2003) describes the matter as follows: "[…] the mere duration of a venture could have little to do with success in business, since a large part of business dissolutions is voluntary". Similarly, plant closures due to the owner's retirement also cannot be considered plant failures.

We believe that it is clear from these arguments that there are a number of different reasons to voluntarily shut down a successful plant and that closure should not be confused with failure.[2] However, is analyzing bankruptcy a better alternative to analyzing failure? The obvious advantage of doing so is that a closed plant that has filed bankruptcy can unambiguously considered a plant failure. The drawback of this approach is that involuntary closures are not treated as plant failures absent a bankruptcy filing. Thus, strictly speaking, our analysis is restricted to involuntary closures that are accompanied by a bankruptcy filing. We also include plants in our analysis for which creditors or debtors filed for bankruptcy but a court refused to initiate the

[2] Coad (2013) proposes to use the term 'death' instead of 'failure'. As 'death' summarizes voluntary and involuntary closures, however, this term is not very useful for our discussion.

formal bankruptcy process because the remaining assets would not be sufficient even to pay the liquidator.[3] Therefore, involuntary closures of businesses with very small assets appear in our data set, and we therefore feel confident that conditioning on a bankruptcy filing is unlikely to result in the loss of economically important cases.

3 The Age-Size Nexus from a Theoretical Perspective

Stinchcombe (1965) inaugurated the analysis of age and organizational mortality. In what follows, we summarize his arguments and their interpretations and refinements by subsequent scholars. Theory can explain both positive and negative age-dependence in failure risk. The two major arguments for positive age-dependence in failure risk are initial endowments and imprinting by founding conditions.

Initial endowments help plants survive a certain period of adverse conditions. Once initial endowments are exhausted, unsuccessful businesses die and prospering businesses survive. Thus, for the individual firm, there is a period of zero risk, followed by a risk peak and declining risk thereafter. If initial endowments are treated as an unobserved random variable in the population (Brüderl and Schüssler 1990), population hazard rates are a smooth, unimodal function of age. These arguments have been summarized as the 'liability of adolescence'. They suggest a period of positive age-dependence at very young ages and negative age-dependence thereafter. Because we have yearly observations, we are not able to detect positive age-dependence if it is concentrated during the first months of plant age.

Imprinting refers to the notion that new firms are well adapted to environmental conditions. This fit will deteriorate if conditions change over time and, hence, the mortality risk increases. The predictions of this approach are similar to those advanced by the theory of **structural inertia** (Hannan and Freeman 1977), which emphasizes that organizations determine (much of) their future paths through their early decisions, which again makes them vulnerable to environmental changes and predicts a liability of obsolescence. The concept of a liability of senescence, as advanced by Barron et al. (1994: 387), emphasizes that "accumulating rules, routines, and structures impedes an organization's ability to act, especially in a timely fashion, in the face of environmental volatility". While the notions of imprinting and inertia

[3] German bankruptcy law distinguishes between consumer bankruptcy and regular bankruptcy, the latter accounting for corporate bankruptcy. According to these regulations, local district courts are responsible for the implementation of bankruptcy proceedings. Bankruptcy proceedings are initiated at the request of creditors or debtors and require illiquidity or over-indebtedness on the part of the firm. The court will not initiate the process if these conditions are not met. The two most important decisions in the course of the process are whether to formally begin the bankruptcy proceeding and whether to reject claims because the remaining assets are insufficient to cover the expenses of the bankruptcy proceedings. Both decisions also underlie the official figures and are part of our data.

predict positive age-dependence in the longer run, initial endowments only have short-term influence. Obsolescence and senescence predict a similar risk-age pattern and cannot be separated in our data (nor in those considered by Barron et al. 1994).

Negative age dependence is predicted by arguments concerning the **quality of decisions** and actions (capabilities) and **positional advantages** developed over time. The quality of decisions, arguably, rises with experience, and this increases productivity and reduces failure risk. Positional advantage is achieved by accumulating trust, reputation, and accountability. This improves relations with external (e.g., customers, government officials) and internal actors (workers, managers), which in turn also improves productivity.[4]

From our perspective, these theoretical arguments can be reduced to two main lines of argument: ageing leads to a productivity-increasing refinement of processes (including internal and external relations) and a declining ability to adapt to changing environments. It is plausible to assume that such refinement begins shortly after plant foundation and should have diminishing returns. The ossification of structures and obsolescence are phenomena associated with higher firm age that should accumulate linearly or progressively. If the short-term effects of initial endowments are ignored, taken together, the theories outlined above predict a U-shaped relationship between failure risk and age.

Uncertainty regarding future performance plays the most prominent role among the explanations for age dependence offered in the industrial economics literature. Jovanovic (1982) models a process in which entering plants are heterogeneous in and uncertain of their costs but learn them after market entry. The market eliminates plants that become high-cost producers. Thus, failure risk and age should be negatively correlated among younger firms but rather uncorrelated among older firms.

It is typically assumed that plant size reduces failure risk. Random shocks can destroy small plants, while larger ones may not even notice the shock. Levinthal (1991) formalized this notion as a random walk through the space of 'organizational capital'. Having little 'organizational capital' increases the risk of being eliminated by a shock, while having a significant amount of this capital helps firms survive even a series of adverse shocks. Economists also tend to emphasize scale effects that may lead to cost advantages. Additionally, larger firms have additional possibilities for portfolio diversification (Markowitz 1952), can typically spread entrepreneurial risks across a larger number of shareholders (Arrow and Lind 1970) and have better access to financial resources (Carreira and Silva 2010). Arguably, larger firms also have greater market power and influence over political decisions.

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[4] For a case in point, see Jirjahn et al. (2011). They provide a theoretical discussion of how the relationship between management and formal employee representation evolves over time and how it may increase firm productivity.

Fackler et al. 2012 provide a recent overview over the considerable body of literature on the effect of size and age on plant exit (i.e. mixing voluntary and involuntary exit). Empirical economic research on the relationships among age, size, and bankruptcy risk is, however, limited. Negative size-dependence was observed by Lennox (1999) for the UK, Honjo (2000) for Japan, and by Mata et al. (2011) for Portugal. In a study on US banks, Wheelock and Wilson (2000) found no evidence for a systematic relationship between size and failure risk. Conversely, Bottazzi and Tamagni (2011) for Italy and Egeln et al. (2010) for Germany found positive size-dependence. Because both studies use samples of smaller or younger firms, their results do not conflict with those of Harhoff et al. (1998), who reported an inverted U-shaped relationship between failure risk and plant size. Further, the negative age-dependence in Harhoff et al. (1998) complements the results obtained by Lennox (1999), who only considered publicly traded and, therefore, on average larger plants. Because the study by Honjo (2000) was restricted to younger plants and Mata et al. (2011) included size in their regression linearly, we conclude that the international literature is in line with the observation of an inverted U-shaped relationship between failure risk and size, as presented by Harhoff et al. (1998) for Germany. The above-mentioned studies by Honjo (2000) and Mata et al. (2011) found negative age-dependence. Harhoff et al. (1998) and Woywode (1998) confirmed this result for Germany.

4 The new Bankruptcy Information

Our new bankruptcy data are obtained from three sources. The largest part is collected routinely by the German Federal Employment Agency's (BA) local branches, but we also employ material from administrative social security notifications and information on bankruptcy filings published by German courts. We describe each source below and begin with the quantitatively most important one.

The German social security system offers compensation (*Insolvenzgeld*) for each employee who has not received his wages due to employer bankruptcy. Each employee is eligible, even employees who are not subject to social security. The BA provides the *Insolvenzgeld*, and each bankruptcy case is administered by one of the 610 local branches of the BA. Our data originate during the administration of the *Insolvenzgeld* and are systematically collected by the BA. The directives pertaining to the implementation of this benefit require close local monitoring, and the employees of the BA are required to not only act on applications but also actively monitor local bankruptcy processes. They are obligated to be up to date regarding the local situation and communicate regularly with the courts that decide the bankruptcy cases. If (upcoming) bankruptcies become known, the BA staff responsible for the *Insolvenzgeld* store information on the status of the case (formal opening of the bankruptcy process, rejection due to a lack of assets, or the final closure of the firm; see §165 SGB III), the bankruptcy date (or the date of the respective event) and additional information relevant for administrative tasks. Importantly, this information is collected, even in the event that no employee applies for *Insolvenzgeld*. We consider the data to be of high quality, as the implementation directives require highly proactive behavior on the part of the BA staff. Moreover, the administration is legally required to check the prerequisites for an application for *Insolvenzgeld*, e.g., by requesting court decisions. However, the current directives regarding local monitoring have been modified and specified in recent years, and we have reason to believe that our data do not cover the entire population of German bankruptcies in the years before 2007. All information is collected in the BA's data warehouse and provided with a plant identifier that allows us to precisely merge the data with other administrative or survey data commonly used by the international research community.[5]

We also consider data from administrative social security notifications. In Germany, every employer must provide notification for each employee subject to social security on at least an annual basis. Moreover, there are also mandatory notifications during the year. According to current legislation (§8a DEÜV), the employer must inform the BA if employees are exempted due to employer bankruptcy. Therefore, this data source is more restrictive than our first source because a firm must exempt at least one of its employees from work. The data are aggregated at the plant level and assigned a plant ID using the same ID scheme as the above-mentioned *Insolvenzgeld* information. Our final data set contains plants with information from both the *Insolvenzgeld* and social security notifications.

Our third data source is collected via publicly accessible information on the universe of all bankruptcies in Germany published by the relevant authorities in an online database (https://www.insolvenzbekanntmachungen.de). This database has been in operation since 2003. The accessible information comprises court decisions and firm characteristics. The major advantage of this data source is its completeness. Unfortunately, it is organized at the firm level, meaning that we cannot identify all plants associated with a given corporation in every case. We use the name and address of the respective corporation from the online notification and match it with the names and addresses in the administrative data collected by the BA. Law prescribes that the authorities must delete a case from the data set at least 6 months after the bankruptcy case has been repealed or dismissed. Our self-collected data comprise information beginning in July 2011.

We combine all three sources of bankruptcy information and merge it with the universe of all German plants with at least one employee subject to social security - the *Betriebshistorikpanel* (BHP).[6] In sum, 216,004 plants with bankruptcy information are identified in the BHP from the years 1996-2011. Of these, 197,454 plants are identified exclusively via the *Insolvenzgeld* and 7,561 plants exclusively via the social security notifications. We have information from both the *Insolvenzgeld* and the

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[5] This includes, for instance, the IAB Establishment Panel, the Linked-Employer-Employee Data (LIAB), and individual-level data (SIAB and IEB) provided by the Institute for Employment Research of the BA (IAB).

[6] The BHP is described in Hethey-Maier and Seth (2010).

social security notifications, for an additional 10,644 plants. Our data set further contains 276 bankrupt plants for which the online data represent the only data source. This number is relatively small because we began gathering information in mid-2011 and the BHP only contains information until the end of 2011 and because we restrict the online data to unambiguous address matches. However, the small number underlines the high degree of completeness provided by the other two sources.

We now outline how plant closure has been approximated in the BHP of the BA and then proceed with a description of our bankruptcy data. The BA assigns a unique plant identifier to each plant and receives compulsory notifications (on at least an annual basis) on the employees for whom the plant must make social insurance contributions. Researchers have used this notification system to proxy for plant exit by analyzing plant identifiers disappearing from the data. If there are no notifications for a certain minimum amount of time, researchers concluded that the plant ceased to exist. The BHP contains several million observations on vanishing establishment IDs.

However, the disappearance of a plant identifier can mean many different things, some of which are not associated with exit. For instance, a change in ownership is typically accompanied by a change in the plant ID (Bender et al. 1996). A clever strategy for obtaining an improved approximation of true exits is to analyze inflow and outflow clusters of employees (e.g., Benedetto et al. 2007, Hethey and Schmieder 2010). If a large segment of the workforce of a plant associated with a vanishing ID continues working under a different plant ID, it is plausible to assume that this is not a true exit. Whether this situation is labeled an ID change, a takeover, or a spin off depends on how large this segment of workers is relative to the successor's overall workforce. Arguably, the best proxy for a true exit is a situation in which the workforce of the closed plant is dispersed over numerous other plants. It is also clear, however, that the direct observation of failure is superior to any approximation.

5 Descriptive Evidence of Bankruptcy Risk

The purpose of this section is to provide first descriptive evidence on involuntary plant closures in Germany using large-scale administrative data. It turns out that most of the descriptive insights are confirmed by the multivariate regression presented in section 6. The empirical analysis is based on the population of all German plants employing at least one worker covered by the social security system (the BHP data). We only include bankruptcies for plants that vanish from the BHP, and we therefore do not consider plants that survived bankruptcy (e.g., by reorganization) or plants that are in the bankruptcy process but are not yet closed. Despite this restriction, and after dropping years prior to 2002 (for which we have very sparse information) and public and primary sector plants, we have 163,579 bankrupt plants that actually vanish from the BHP data.

We begin with a description of bankruptcy risk and define bankruptcy risk as the fraction of plants that, in a given period, files for bankruptcy *and* exits the market among all plants that either remain in business or exit the market due to bankruptcy.[7] We therefore exclude plants that exit the market without bankruptcy from the numerator and denominator of this fraction because this group contains both voluntary and involuntary exits and cases in which plant identifiers vanish although the plant remains in the market. Excluding these plants yields a properly defined control group against which involuntary closure can be evaluated.

Figure 1 describes the number of bankrupt plants in our data set that left the market during the period from 2002 to 2011. For the reasons given in the previous section, we believe that the data are incomplete for years prior to 2007 and do not include these data in further analysis. Beginning with 2007, we have complete information in the sense described in section 4. The graph nicely illustrates the consequences of the economic crisis that began to affect Germany in the last quarter of 2008 and endured in 2009: while the number of market exits due to bankruptcy increased in 2008 and 2009, it began to decline in 2010. Because the German economy was in excellent condition in 2010, the relatively high number of bankruptcies in that year and in 2011 indicates a considerable time lag between aggregate economic shocks and bankruptcies. Two possible explanations for such lags are contagion effects (Benmelech and Bergman 2011) and the length of administrative bankruptcy procedures ultimately resulting in restructuring or plant closure.

Figures 2 and 3 illustrate bankruptcy risks by age and size, respectively, for the years with full information, representing a total of 86,824 bankrupt plants.[8] Age and size refer to the last 30th of June prior to exit, meaning that exit may occur by the 29th of June of the next year. Here and in the multivariate analysis below, we do not present figures for the year 2011 because we lack complete information regarding exits in the first half of 2012. Figure 2 clearly shows strong negative age dependence in failure risk. While plants older than 20 years face a bankruptcy risk of approximately 0.5 percent, this figure is roughly 5 times larger for newly founded plants. Failure risk decreases non-linearly with plant age and levels out at a failure risk of approximately 0.5 percent. The descriptive analysis therefore yields no evidence in favor of the theoretical approaches stressing imprinting or structural inertia, both of which predict positive age dependence, or a liability of senescence, which predicts positive age dependence at higher ages.

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[7] Because we intend to measure involuntary closures, our definition of bankruptcy risk deliberately assigns plants that survive the bankruptcy process to the denominator.

[8] Throughout the paper, we will use the same age and size categories as presented in the figures. The categories are chosen such that there is a sufficient number of observations per category interaction, e.g. plants being small and old. Note that we don't opt for continuous age and size variables as it turns out that restrictions such as linearity or log-linearity in the interaction effects are not supported by our multivariate results.

Figure 3 presents descriptive evidence for negative size dependence in failure risk. Size dependence, however, is less pronounced than age dependence. In 2007 and 2010, plants with over 50 employees face a bankruptcy risk that is approximately half the risk of the smallest plants. During the crisis, the risk increases for all size classes. The figure also indicates that the crisis-related relative and absolute increase in failure risk is highest for plants with over 50 employees and smallest for plants with fewer than 4 employees. The failure risk for large plants was 80 (64) percent higher in 2009 than in 2007 (2010).[9]

Comparing Figures 2 and 3 reveals that failure risk is more related to age than size and risks can be clearly ordered by age and, to some extent, by size. Hannan et al. (1998) argued that age-dependency varies with size. To analyze this relationship, we tabulate failure risk using our age and size categories for the period 2007 - 2010 in Table 1. Again, the failure risk is highest for the youngest plants (2.4 percent out of 1.44 million observations). At 2.1 percent, the smallest plants have the *lowest* failure risk among all young plants. Because of the large number of small and young plants, however, this group alone accounts for 24.8 percent of all bankruptcies. Young plants with 4 to 10 (11 to 50) employees face a risk of approximately 3.1 (3.3) percent, which amounts to a relative risk premium over smaller young plants of approximately 50 percent. The within age-group pattern remains unchanged for the two subsequent age categories, while the overall risk declines sharply from 2.4 percent for the youngest plants compared to 0.8 percent for 6- to 10-year-old plants. The risk declines further for plants older than 10 years, and within age group risk is now largest for the smallest plants. Among the youngest plants, the largest plant's risk is approximately 2.5 percent; therefore, placing their risk between those of the smallest and medium-sized plants. For large plants, age dependence is much more pronounced; hence, failure risk is lowest among 3- to 20-year-old plants.[10]

Approximately 83 percent of all bankruptcies occur among plants with no more than 10 employees, and 61 percent of all bankrupt plants are not older than 5 years. Plants meeting both criteria account for 53 percent of all bankruptcies. Although this is a large percentage, it also implies that firms with more than 10 employees and/or those over 5 years of age represent approximately half of all bankruptcies. The conclusion that bankruptcy is primarily a phenomenon affecting small entrants is therefore misguided.

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[9] Computing plant age from the first appearance of a plant ID in the data can lead to underestimation of true plant age, as a new plant ID may, e.g., reflect a change in ownership instead of the true date of plant foundation. Note that all of our results with respect to age dependence hold if we use worker flows to indicate and exclude ambiguous entries (see Hethey and Schmieder 2010). However, using worker flows to exclude ambiguous entries yields a somewhat more pronounced negative size dependence. See the corresponding results in the Appendix. We do not employ the restricted sample in subsequent analysis, as a considerable number of plants are dropped due to missing values in the entry classification scheme.

[10] As discussed previously, all results of the cross tabulation remain qualitatively unchanged when excluding ambiguous entries.

The overall descriptive picture indicates that age is important for all size categories but primarily affects medium-sized and larger plants. Age-dependence is not only weaker for smaller plants, but it is also concentrated within the first 5 years of operation, meaning that failure risk is similar for 6- to 10-year-old small plants and very old small plants. The weaker age-dependence among small plants can be explained by their smaller initial investments: this weaker age-dependence avoids high debt levels during their vulnerable early years but comes at the cost of a lack of the longer-term protection that may result from high initial investments. Another possible explanation for the weaker age-dependence is that many plants of this size are merely trial-and-error endeavors (Headd 2003) or successful closures (Bates 2005, Taylor 1999) that either do not incur debts or repay them prior to closing. There may also be cases of plant failure in which creditors do not initial bankruptcy proceedings because the assets at stake are simply not worth the effort. For the reasons described in section 4, however, we do not believe that this is an important phenomenon in our data.

6 Multivariate Analysis

We begin the multivariate analysis of the relationships among age, size, and failure risk with a simple linear probability model with interactions between age and size. We will use information encompassing the years from 2007 to 2010. The 24 interaction terms are formed from the 6 age categories and the 4 size categories described in Table 1; the group formed by the oldest and largest plants serves as the reference category. The regression coefficients for the age-size dummies therefore reflect ceteris paribus differences in failure risk relative to this group. Statistical significance is evaluated using standard errors clustered at the plant level. Coefficients of the age-size interactions are typically statistically significant at the 1 percent level in all samples and specifications. The only coefficients that are insignificant or significant only at the 10 percent level belong to large plants older than 10 years.

Panel A in Table 3 represents a specification that only controls for sector and year. It reveals negative age dependence across all size classes and negative size dependence only among older plants. The multivariate results therefore confirm the descriptive evidence presented in Table 1. This finding is interesting because it implies that the effects of age and size are independent of sector affiliation.[11]

[11] Note that our results for size dependence in failure risk could be influenced by what Griliches and Regev (1995) have termed the “shadow of death”. A “shadow of death” in employment means that plants shrink for a considerable amount of time before they ultimately exit the market (see also Fackler et al. 2013). In our data, plant size categories are defined by the number of employees on the last 30th of June on which the plant exists and may therefore not reflect the plant’s long-run employment level. However, a “shadow of death” cannot explain why we do not find negative size dependence because any reduction in employment just prior to exit moves bankrupt plants into lower size categories and would therefore artificially produce negative size dependence.

Workforce composition may be correlated with plant size, plant age, and failure risk. We therefore add controls for the composition of the workforce by including the shares of part-time and full-time employees, women, and apprentices. We additionally control for occupations using the Blossfeld (1987) classification (see Hethey-Maier and Seth 2010). The share of workers within each occupational category should proxy for the plant's skill composition. Because failure risk may differ between East and West Germany, we add a dummy variable where a value of 1 indicates East Germany. Moreover, the age of the workforce might be correlated with plant age and size. We therefore add the shares of workers who are less than 34 years old, between 35 and 49, or 50 and above.

Table 2 presents descriptive statistics at the plant level. A smaller plant generally has higher shares of female workers, part-time workers working fewer than 18 hours, and workers in agricultural and simple administrative occupations.[12] Simple manual workers, technicians, semi-professionals, and engineers constitute a higher share of the workforce in larger plants. In very small plants, the share of younger workers is low, and the share of older workers is high.

The coefficients for the control variables employed in the linear probability model are presented in Table 4. Most coefficients are highly statistically significant but small in absolute terms. For many regressors, the relative change in failure risk is nevertheless substantial because the absolute failure risk is only 1.1 percent. Table 4 indicates that a higher share of part-time and female workers is associated with lower failure risk. Because these are precisely the categories overrepresented in smaller plants, ceteris paribus, we expect an increase in the failure risk of smaller plants relative to larger plants when controlling for these categories in the regression. That simple manual workers are overrepresented in larger plants and the coefficients for this group are positive should work in the same direction. The negative signs for technicians, semi-professionals, and engineers may mute this effect, but employment shares in these categories are quite small, and their impact is thus limited. Panel B of Table 3 (and graphically, Figure 4) presents the corresponding coefficients for the age-size interactions and clearly demonstrates an increase in the risk of smaller firms relative to the results in Panel A. Thus, smaller firms employ higher shares of workers who are associated with *lower* failure risk. The results confirm negative age dependence but also reveal negative size dependence among plants 6 years of age or older. The latter result was not clear based on the descriptive evidence.

[12] The share of part-time workers working fewer than 18 hours per week may seem implausibly high at first glance, in particular within smaller plants. The figures represent means over plant-level averages, such that each plant has the same weight. Within each size category, the smallest plants constitute the highest share among all plants, and hence, employment shares at the plant level may be very different from the corresponding shares at the worker level, as is typically reported in official statistics.

Because of the different historical conditions and differences in industrial structure between West and East Germany (the former socialist GDR), it is natural to expect differences in failure risk between the parts of the country. Surprisingly, the mean difference between the regions (conditional on age, size, sector affiliation and workforce composition) is negligible (+0.075 percentage points in East Germany; Table 4). Moreover, the patterns of age and size dependence seem to be very similar, as observed by comparing Panels B and C of Table 3, the latter presenting results for West Germany alone.

The theoretical arguments outlined in section 3 imply that older and larger firms are more likely to survive due to their higher productivity. Higher productivity can be achieved through either the continued refinement of production processes (older plants), via producing above the minimum efficient scale (larger plants), or the positional advantages that may help older and/or larger firms attract high-ability workers who decrease failure risk. Strictly speaking, the theoretical arguments imply that the age and size regressors capture between-plant productivity differences that reside in the error term of the regression equations presented thus far. Making productivity observable should therefore reduce the relative advantage of older and/or larger plants. From this perspective, separating productivity differences from the error term serves as an indirect test of whether age- and size-dependence can be explained by productivity differences as suggested by theory.

We use the plant's wage level (i.e., the 25th, 50th, and 75th percentiles of each plant's wage distribution) to proxy for unobserved productivity differences. Table 2 reveals substantial wage differentials between larger and smaller plants. For instance, the median daily wage in very small plants is only approximately one third the median wage of plants with over 11 employees. Of course, these plant-size wage differentials also stem from differences in the shares of part-time and female workers. However, the wage levels have highly significant coefficients even after controlling for workforce composition. They are negative at all quartiles of the wage distribution (Table 4) and imply that higher wages are, ceteris paribus, associated with lower failure risk. The sign of the coefficients implies that the wage coefficients do not measure the causal effect of *wage costs* (this effect should be positive) but rather seem to capture the effects of unobserved productivity differences that influence failure risk. Our results regarding age-size dependence in failure risk when including wage controls are presented in the two bottom panels of Table 3. They clearly demonstrate that controlling for wages reduces the relative advantage of older and larger plants.[13] We therefore find evidence supporting the productivity-related explanations of negative age- and size dependence in failure risk.[14]

Finally, we assess whether our results differ between manufacturing plants and plants from other sectors. This is an interesting comparison because manufacturing endeavors are more likely to reflect technological progress than, e.g., small retail stores, bars, or restaurants. Restricting our regressions to the manufacturing sector, we generally obtain very similar results: there is negative age dependence and negative size dependence for mature plants. Generally, age dependence and size dependence are even more pronounced in the manufacturing sector. As in the full sample, these effects are muted when controlling for wages, although only the median wage is statistically significant in these estimates.

7 Conclusions

This paper introduces a new, large-scale administrative data set on plant bankruptcy in Germany. Many studies seek to explain plant failure but actually observe plant exit. We argue that bankruptcy measures economic failure and plant exit does not. To our knowledge, this is the first study that describes plant bankruptcy and, thus, involuntary exit in Germany using administrative data.

Our descriptive evidence indicates that bankruptcy risk declines sharply in plant age. For younger plants, we observe a hump-shaped relationship between plant size and failure risk and therefore confirm the results in Harhoff et al. (1998). Age dependency is non-linear, with the sharpest decline at young ages and rather modest reductions for plants older than 10 years. This pattern holds for all plant sizes but is less pronounced for the smallest plants, which is also the group that exhibits the *lowest* bankruptcy risk among all young plants. Interestingly, recent empirical evidence on the determinants of plant exit (i.e., not on bankruptcy) obtained by Fackler et al. (2012) suggests a *higher* closure propensity for young plants if they are also small. One reason for the weaker age-dependence among smaller plants in bankruptcy risk but not in the exit rate might be that many plants of this size are merely trial-and-error endeavors (Headd 2003) or successful closures (Bates 2005, Taylor 1999) that simply repay their debts before exiting the market. To avoid the impression that bankruptcy is primarily a concern among small entrants, we note that this

[13] As discussed previously, all results remain qualitatively unchanged when we exclude ambiguous entries.

[14] Comparing columns (1) and (3) of Table 4 reveals that controlling for wages reverses the sign of the East Germany dummy. Thus, conditional on the same wage structure, East German plants are, ceteris paribus, less likely to fail than their West German competitors. Because East German wages and productivity levels are on average much lower than those in West Germany, conditioning on wages implies comparing a high-wage (high-productivity) East German plant with a low-wage (low-productivity) West German plant. As long as the relative position in the local productivity distribution affects bankruptcy risk, the change in the sign of the East Germany regressor demonstrates that wages capture unobserved productivity differences that would otherwise be reflected in the coefficients of other regressors, whether in the region dummy or in the age or size dummies.

group of plants (i.e., no more than 10 workers *and* no more than 5 years old) represents 53 percent of all bankruptcies, only.

The descriptive evidence on bankruptcy risk is generally confirmed by the multivariate regression analysis. The regression analysis also reveals a negative size-dependence for plants that are at least 6 years old. Smaller plants employ higher shares of part-time and female workers, and we find that plants employing more of these types of workers, ceteris paribus, face a lower failure risk. Moreover, the share of simple manual occupations is higher in larger plants and is, ceteris paribus, positively associated with failure. Thus, between-plant differences in workforce composition do not explain negative size dependence.

The most prominent theoretical argument for negative age dependence stresses higher productivity due to the refinement of production processes and improvements in intra- and inter-firm relations. We do not directly observe production processes or firm relations, and hence, such productivity advantages are unobserved and enter the error term of our regressions. However, higher productivity serving as the causal mechanism for negative age- and size-dependence is indirectly confirmed by our analysis because controlling for the plant-level wage structure as a proxy for unobserved between-plant productivity differences substantially reduces the disadvantage of smaller and younger plants. All of our results persist when examining the manufacturing sector in isolation.

In sum, our results are not consistent with a pure explanation of imprinting (Stinchcombe 1965) or structural inertia (Hannan and Freeman 1977), both of which predict positive age dependence due to a worsening fit between firm structure and the state of the world. We are also unable to detect a 'honeymoon period', as in Fichman and Levinthal (1991), or a liability of senescence, as proposed by Barron et al. (1994). The results are, however, perfectly consistent with explanations related to increasing capabilities (Stinchcombe 1965) and positional advantage, both of which predict negative age dependence, due to productivity improvements stemming from processes of learning or reputation building, respectively. Of course, negative age dependence among younger but not older plants is also in line with the predictions of learning models (Jovanovic 1982).

While this paper establishes basic facts about the determinants of bankruptcy using a new and comprehensive data set on Europe's leading economy, future research should also focus on the importance of initial conditions. It would also be interesting to determine whether bankruptcy is the immediate consequence of a sudden shock or the outcome of long-lasting deteriorations in economic performance.

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Tables

Table 1
Bankruptcy Risk by Age and Size (in %), Years 2007 - 2010

	Plant Age in years							
Number of Workers		0-2	3-5	6-10	11-20	>20 but founded after 1975	founded before 1975	Total
	1-3	2.08 (24.8)	1.32 (12.0)	0.73 (8.5)	0.67 (6.1)	0.59 (2.1)	0.64 (1.4)	1.15 (55.0)
		1,038	789	1,016	798	318	191	4,149
	4-10	3.06 (10.1)	1.68 (6.1)	0.93 (4.9)	0.57 (4.0)	0.46 (1.5)	0.43 (1.2)	1.10 (27.8)
		287	316	455	601	279	249	2,187
	11-50	3.26 (4.4)	1.80 (2.9)	1.01 (2.5)	0.64 (2.5)	0.49 (1.0)	0.50 (1.3)	1.04 (14.7)
		118	139	217	347	175	227	1,223
	>50	2.45 (0.6)	1.18 (0.4)	0.72 (0.4)	0.48 (0.4)	0.50 (0.2)	0.52 (0.5)	0.73 (2.5)
		20	26	44	80	39	90	299
	Total	2.37 (39.9)	1.46 (21.4)	0.81 (16.3)	0.62 (13.1)	0.52 (4.8)	0.51 (4.5)	1.10 (100)
		1,436	1,271	1,732	1,825	810	757	7,858

Notes: East and West Germany, private sector without mining, fishing and agriculture, and hunting and forestry. Bankruptcy risk is measured on an annual basis. Thus, the figures are means (not sums) over years. Numbers in parentheses reflect the percentage share of the respective group among all 86,824 bankruptcies in the time period considered. The number of all plant-year observations (in 1000) is given below the percentages.

Table 2
Descriptive Statistics for Covariates by Plant Size, Years 2007 to 2010

	1-3 workers	4-10 workers	11-50 workers	> 50 workers
East Germany	0.196	0.187	0.173	0.173
Share in total workforce:				
Workers < 35 years	0.256	0.344	0.357	0.335
Workers 35-49 years	0.400	0.391	0.391	0.412
Workers ≥ 50 years	0.343	0.265	0.251	0.254
Apprentices	0.028	0.049	0.051	0.041
Part-time Workers, < 18 hours/week	0.471	0.325	0.245	0.152
Part-time Workers, ≥ 18 hours/week	0.098	0.099	0.092	0.104
Female Workers	0.564	0.529	0.448	0.389
Job categories:				
Agricultural occupations	0.034	0.028	0.022	0.017
Simple manual	0.065	0.079	0.106	0.175
Simple service	0.240	0.205	0.227	0.207
Simple administrative	0.163	0.162	0.147	0.117
Qualified manual	0.123	0.180	0.183	0.143
Qualified service	0.056	0.051	0.025	0.015
Qualified administrative	0.250	0.204	0.191	0.217
Technicians	0.021	0.030	0.035	0.045
Semiprofessionals	0.005	0.005	0.007	0.007
Engineers	0.010	0.013	0.017	0.027
Professionals	0.004	0.010	0.008	0.005
Managers	0.029	0.032	0.032	0.024
Daily wage (Quantiles; in Euro):				
25^{th}	22.70	47.63	61.11	73.33
Median	24.35	56.32	72.09	85.96
75^{th}	25.97	65.47	85.35	103.07
Plant/Year Observations	4,115,869	2,186,095	1,221,711	298,968

Notes: East and West Germany, private sector without mining, fishing and agriculture, and hunting and forestry. Descriptive statistics for the sample used in the regression that controls for wages. Figures represent means over plants.

Table 3
Coefficients for Age-Size Interactions, Years 2007 to 2010

	Number of Employees			
	1-3	4-10	11-50	>50
	Panel A: East and West Germany, only year and sector controls			
0-2 years	0.020	0.028	0.029	0.020
3-5 years	0.013	0.015	0.015	0.007
6-10 years	0.008	0.008	0.007	0.003
11-20 years	0.006	0.004	0.003	0.000
>20 years, uncensored	0.005	0.003	0.002	0.000
>32 years, censored	0.005	0.002	0.001	Reference
	Panel B: East and West Germany, full controls w/o wage			
0-2 years	0.023	0.030	0.030	0.020
3-5 years	0.017	0.017	0.016	0.007
6-10 years	0.012	0.010	0.008	0.003
11-20 years	0.009	0.006	0.004	0.000
>20 years, uncensored	0.009	0.006	0.003	0.001
>32 years, censored	0.008	0.005	0.003	Reference
	Panel C: West Germany, full controls w/o wage			
0-2 years	0.023	0.029	0.029	0.019
3-5 years	0.017	0.017	0.015	0.008
6-10 years	0.013	0.010	0.008	0.003
11-20 years	0.010	0.007	0.004	0.000
>20 years, uncensored	0.008	0.006	0.003	0.001
>32 years, censored	0.008	0.005	0.003	Reference
	Panel D: East and West Germany, full controls including wages			
0-2 years	0.020	0.027	0.028	0.019
3-5 years	0.013	0.014	0.013	0.006
6-10 years	0.009	0.007	0.006	0.002
11-20 years	0.006	0.003	0.002	-0.001
>20 years, uncensored	0.006	0.004	0.002	0.000
>32 years, censored	0.006	0.003	0.001	Reference
	Panel E: West Germany, full controls including wages			
0-2 years	0.020	0.026	0.027	0.018
3-5 years	0.014	0.014	0.013	0.008
6-10 years	0.010	0.008	0.006	0.003
11-20 years	0.007	0.004	0.003	0.000
>20 years, uncensored	0.005	0.003	0.002	0.000
>32 years, censored	0.006	0.003	0.001	Reference

Notes: Dependent variable: dummy indicating exit due to bankruptcy in the exit year. Private sector without mining, fishing and agriculture, and hunting and forestry. Coefficients are typically statistically significant at the 1 percent level (standard errors are clustered at the plant level). The only coefficients that are insignificant or significant only at the 10 percent level belong to large plants older than 10 years. Regressions that include wage quantiles also include a dummy variable for plants with missing wage information. Results for covariates are presented in Table 4.

Table 4
Coefficients for Covariates, Years 2007 to 2010

	Germany	West Germany	Germany	West Germany
East/100	0.075***	---	-0.033***	---
Share in total workforce:				
Workers < 35 years	0.001***	0.001***	-0.000	-0.004**
Workers ≥ 50 years	-0.001***	-0.001***	-0.001***	-0.001***
Apprentices	0.000	0.000	0.001**	0.000
Part-time Workers, < 18 hours/week	-0.011***	-0.012***	-0.010***	-0.011***
Part-time Workers, ≥ 18 hours/week	-0.005***	-0.005***	-0.003***	-0.003***
Female Workers	-0.003***	-0.003***	-0.005***	-0.004***
Job categories:				
Simple manual occupations	0.008***	0.008***	0.007***	0.007***
Simple service	0.001***	0.002***	0.001**	0.001***
Simple administrative	-0.001**	-0.001*	0.000	0.000
Qualified manual	-0.001***	0.000	-0.001***	0.000
Qualified service	-0.005***	-0.004***	-0.004***	-0.004***
Qualified administrative	-0.002***	-0.002***	-0.001***	-0.001***
Technicians	-0.005***	-0.004***	-0.002***	-0.002***
Semiprofessionals	-0.016***	-0.015***	-0.015***	-0.014***
Engineers	-0.008***	-0.008***	-0.002***	-0.003***
Professionals	-0.007***	-0.006***	-0.003***	-0.002***
Managers	0.000	-0.001***	0.003***	0.002***
Daily wage (Quantiles; in 1000 Euro):				
25th	---	---	-0.023***	-0.018***
Median	---	---	-0.071***	-0.074***
75th	---	---	-0.020***	-0.021***
Year 2008	0.003***	0.003***	0.003***	0.003***
Year 2009	0.003***	0.004***	0.004***	0.004***
Year 2010	0.004***	0.004***	0.004***	0.004***
Observations	7,822,643	6,342,114	7,822,643	6,342,114
Plants	2,558,135	2,070,586	2,558,135	2,070,586

Notes: Dependent variable: dummy indicating exit due to bankruptcy in the exit year. Private sector without mining, fishing and agriculture, and hunting and forestry. Columns (1) and (3) refer to Germany as a whole and correspond to the upper middle and lower left panels of Figure 4. Columns (2) and (4) refer to West Germany and correspond to the upper right and lower middle panels of Figure 4. ***, **, and * denote statistical significance at the 1, 5, and 10 percent levels, respectively, and is derived from standard errors that are clustered at the plant level. Regressions that include wage quantiles also include a dummy variable for plants with missing wage information.

Figures

Figure 1
Number of Bankrupt Plants leaving the Market (by Year)

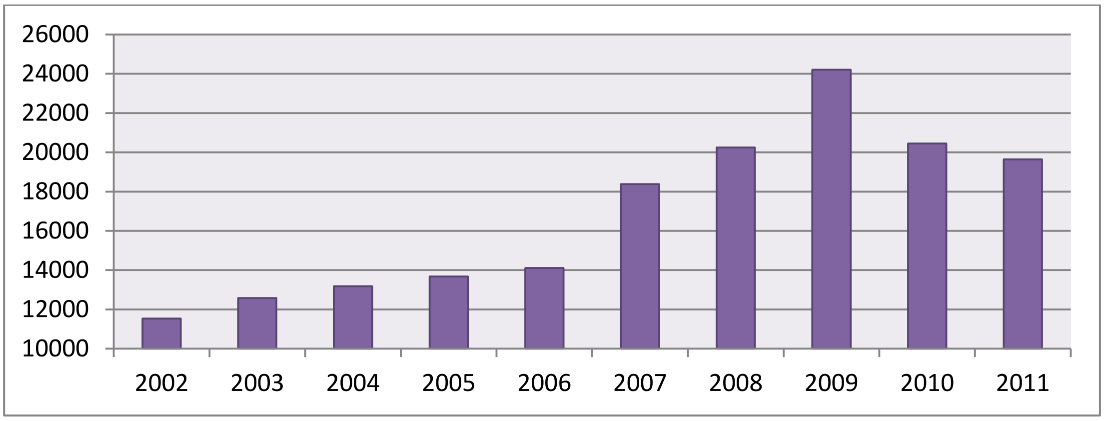


Figure 2
Bankruptcy Risk by Plant Age and Year (Years 2007 – 2010)

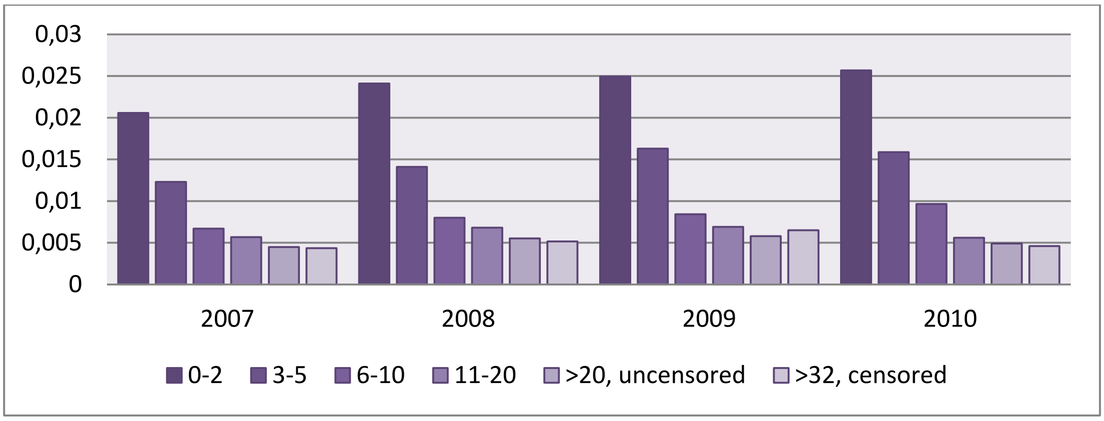
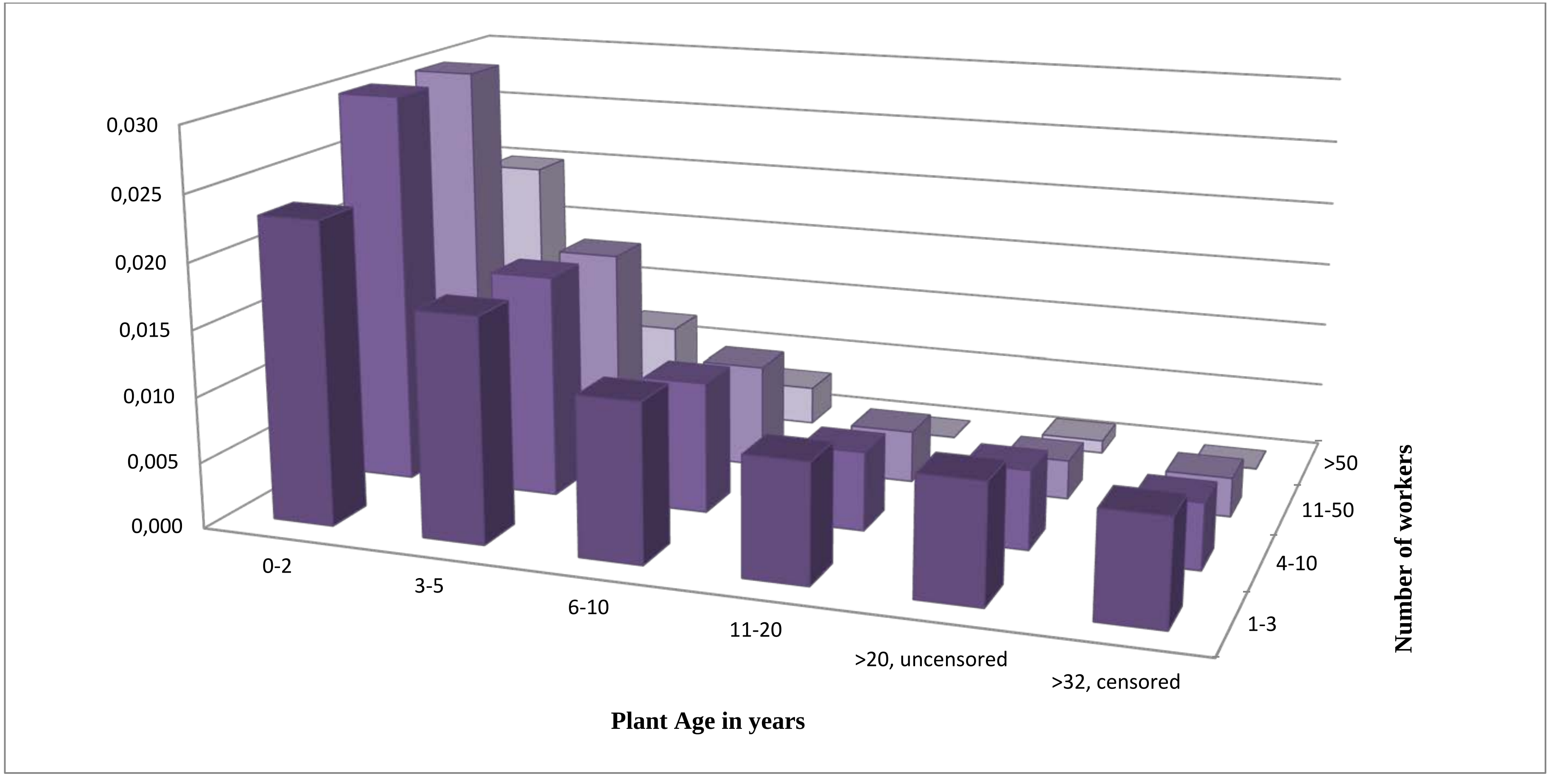


Figure 3
Bankruptcy Risk by Plant Size and Year (Years 2007 – 2010)

Figure 4
Effects on Bankruptcy Risk, OLS Coefficients for Interaction Terms of Plant Age and Size (Years 2007-2010)



Notes: The figures illustrates the results presented in Panel B of Table 3, i.e. East and West Germany with control variables excluding wages

Appendix

Figure A1
Bankruptcy Risk by Plant Age and Year (Years 2007 – 2010), w/o ambiguous entries

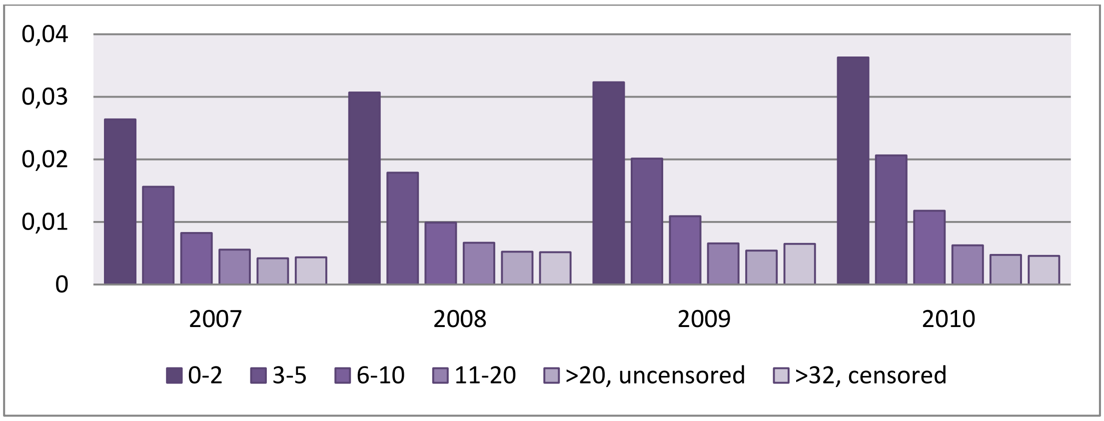


Figure A2
Bankruptcy Risk by Plant Size and Year (Years 2007 – 2010), w/o ambiguous entries

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IAB-Discussion Paper 13/2014

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ISSN 2195-2663

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