

Modeling Credit Risk for SMEs: Evidence from the US Market

EDWARD I. ALTMAN AND GABRIELE SABATO

Considering the fundamental role played by small and medium sized enterprises (SMEs) in the economy of many countries and the considerable attention placed on SMEs in the new Basel Capital Accord, we develop a distress prediction model specifically for the SME sector and to analyze its effectiveness compared to a generic corporate model. The behaviour of financial measures for SMEs is analyzed and the most significant variables in predicting the entities' credit worthiness are selected in order to construct a default prediction model. Using a logit regression technique on panel data of over 2,000 US firms (with sales less than \$65 million) over the period 1994-2002, we develop a one-year default prediction model. This model has an out-of-sample prediction power which is almost 30 percent higher than a generic corporate model. An associated objective is to observe our model's ability to lower bank capital requirements considering the new Basel Capital Accord's rules for SMEs.

JEL classification: G21; G28

Key words: SME finance; Modeling credit risk; Basel II; Bank capital requirements

EDWARD ALTMAN (ealtman@stern.nyu.edu) is the Max L. Heine Professor of Finance at the Leonard N. Stern School of Business at the New York University and GABRIELE SABATO (info@gabrielesabato.it) is a Ph.D in finance and scoring consultant at ABN AMRO (Amsterdam).

1. Introduction

Small and medium sized enterprises are reasonably considered the backbone of the economy of many countries all over the world. For OECD members, the percentage of SMEs out of the total number of firms is greater than 97 percent. In the US, SMEs provide approximately 75 percent of the net jobs added to the economy and employ around 50 percent of the private workforce, representing 99.7 percent of all employers¹. Thanks to the simple structure of most SMEs, they can respond quickly to changing economic conditions and meet local customers' needs, growing sometimes into large and powerful corporations or failing within a short time of the firm's inception². From a credit risk point of view, SMEs are different from large corporates for many reasons. For example, Dietsch and Petey (2004) analyze a set of German and French SMEs and conclude that they are riskier but have a lower asset correlation with each other than large businesses. Indeed, we hypothesize that applying a default prediction model developed on large corporate data to SMEs will result in lower prediction power and likely a poorer performance of the entire corporate portfolio than with separate models for SMEs and large corporates.

The main goal of this paper is to analyze a complete set of financial ratios linked to US SMEs and find out which are the most predictive variables affecting an entities' credit worthiness. One motivation is to show the significant importance for banks of modeling credit risk for SMEs separately from large corporates. The only study that we are aware of that focused on modeling credit risk specifically for SMEs is a fairly distant article by Edmister (1972). He analyzed 19 financial ratios and, using multivariate discriminant analysis, developed a model to predict small business defaults. His study examined a sample of small and medium sized

¹ Statistics provided by the *United States Small Business Administration*, www.sba.gov. Similar data apply in other countries, like Australia.

² See for example OECD outlook on SMEs (2002).

enterprises over the period 1954-1969. We expand and improve his work using, for the first time, the definition of SME as contained in new Basel Capital Accord (sales less than €50 million) and applying a logit regression analysis to develop the model. We extensively analyze a large number of relevant financial measures in order to select the most predictive ones. Then, these variables are used as predictors of the default event. The final output is not only an extensive study of SME financial characteristics, but also a model to predict their probability of default (PD), specifically the one year PD required under Basel II³. The performance of this model is also compared with the performance of a well-known generic corporate model (known as Z''-Score⁴) in order to show the importance of modeling SME credit risk separately from a generic corporate model. We acknowledge that our analysis could still be improved using qualitative variables as predictors in the failure prediction model to better discriminate between SMEs (as recent literature, e.g. Lehmann (2003) and Grunet et al. (2004), demonstrate). The COMPUSTAT database used, however, does not contain qualitative variables. Nevertheless, the performance accuracy of the model used to predict SME default is significantly high both on an absolute and relative basis⁵.

While there have been many successful models developed for corporate distress prediction purposes, and at least two are commonly used by practitioners on a regular basis, none were developed specifically for SMEs⁶. In addition, those original Z-Score models (developed by one of the authors) can be improved upon by transforming several of the variables to adjust for the changing values and

³ Basel Committee on Banking Supervision, June 2004.

⁴ This is a model for manufacturing and non manufacturing firms, see Altman and Hotchkiss (2005). This model is of the form Z''-Score= $6.56X_1+3.26X_2+6.72X_3+1.05X_4$, where :

X_1 = working capital/total assets;
 X_2 =retained earnings/total assets;
 X_3 =EBIT/total assets;
 X_4 =book value equity/total assets.

⁵ COMPUSTAT North America (Standard & Poor's Corp., a division of Mc Graw-Hill Corp.) is a database of US and Canadian financial and market information on more than 24,000 active and inactive publicly held companies.

⁶ We refer to the KMV model, now owned and marketed by *Moody's/KMV*, and the Altman Z-Score model (available from *Bloomberg*, *S&P's Compustat* and several other vendors).

distributions of several of the key variables of those models. In particular, a parsimonious selection of variables, some of which are transformed, can compensate for the fact that our model cannot make use of qualitative variables that are available only from banks' and other lending institutions' files⁷.

The analysis is carried out on a sample of 2,010 US firms (with sales less than \$65 million) including 120 defaults, spanning the time period 1994 to 2002⁸. Section 2 provides a survey of the most relevant literature about failure prediction methodologies. First, the choice of using a logistic regression to develop a specific SME credit risk model is addressed and justified. Then, follows an overview and analysis of the findings of the most recent studies about SMEs. Section 3 develops a model to predict one-year SME default. We examine different statistical alternatives to improve the performance of our model and compare the results. Results using a logistical technique are contrasted with other alternatives, principally discriminant analysis. Section 4 emphasises the value of developing a specific model in order to estimate SME one-year probability of default. In particular, the benefits, in terms of lower capital requirements for banks of applying a specific SME model are shown. We demonstrate that improving the prediction accuracy of a credit risk model is likely to have beneficial effects on the Basel II capital requirements for SMEs when the Advanced Internal Rating Based (A-IRB) approach is used and, as such, could result in lower interest costs for SME customers. Section 5 provides our conclusions.

⁷ We are aware that most large banks have recently been motivated to develop models specifically for SMEs since the new Basel Accord explicitly differentiates capital requirements between large corporates and SMEs.

⁸ This sales limit of \$65 million (the equivalent of €50 million) comes from the new Basel Capital Accord's definition of a SME (June 2004). Perhaps, \$50 million in the US and (say) A\$50 million in Australia will be the definitions to be implemented in those countries. In our precedent work (Altman and Sabato, 2005), we have analyzed the different SME definitions for Europe, US and Australia and explored the expected capital requirements for SMEs under the Basel II Accord. We believe that banks now consider the Basel II definition as prominent.

2. Review of the relevant research literature

This Section reviews some of the most important works about failure prediction methodologies. After first analyzing the most popular alternative statistical techniques that can be used to develop credit risk models, focus switches to the works that have investigated the problem of modeling credit risk for small and medium sized firms.

2.1 Default prediction studies

The literature about default prediction methodologies is substantial. Many authors during the last 40 years have examined several possible realistic alternatives to predict customers' default or business failure. The seminal works in this field were Beaver (1967) and Altman (1968), who developed univariate and multivariate models to predict business failures using a set of financial ratios. Beaver (1967) used a dichotomous classification test to determine the error rates a potential creditor would experience if he classified firms on the basis of individual financial ratios as failed or non-failed. He used a matched sample consisting of 158 firms (79 failed and 79 non-failed) and he analyzed 14 financial ratios. Altman (1968) used a multiple discriminant analysis technique (MDA) to solve the inconsistency problem linked to the Beaver's univariate analysis and to assess a more complete financial profile of firms. His analysis drew on a matched sample containing 66 manufacturing firms (33 failed and 33 non-failed) that filed a bankruptcy petition during the period 1946-1965. Altman examined 22 potentially helpful financial ratios and ended up selecting five as providing in combination the best overall prediction of corporate bankruptcy⁹. The variables were classified into five standard ratios categories, including liquidity, profitability, leverage, solvency and activity ratios.

⁹ The original Z-score model (Altman, 1968) used five ratios: Working Capital/Total Assets, Retained Earnings/Total Assets, EBIT/Total Assets, Market Value Equity/BV of Total Debt and Sales/Total Assets.

For many years thereafter, MDA was the prevalent statistical technique applied to the default prediction models. It was used by many authors (Deakin (1972), Edmister (1972), Blum (1974), Eisenbeis (1977), Taffler and Tisshaw (1977), Altman et al. (1977), Bilderbeek (1979), Micha (1984), Gombola et al. (1987), Lussier (1995), Altman et al. (1995)). However, in most of these studies, authors pointed out that two basic assumptions of MDA are often violated when applied to the default prediction problems¹⁰. Moreover, in MDA models, the standardized coefficients cannot be interpreted like the slopes of a regression equation and hence do not indicate the relative importance of the different variables. Considering these MDA's problems, Ohlson (1980), for the first time, applied the conditional logit model to the default prediction's study¹¹. The practical benefits of the logit methodology are that it does not require the restrictive assumptions of MDA and allows working with disproportional samples. Ohlson used a data set with 105 bankrupt firms and 2,058 non-bankrupt firms gathered from the COMPUSTAT database over the period 1970-1976. He based the analysis on nine predictors (7 financial ratios and 2 binary variables), mainly because they appeared to be the ones most frequently mentioned in the literature. The model's performance, in terms of classification accuracy, was lower than that reported in the previous studies based on MDA (Altman, 1968 and Altman et al., 1977). But reasons were provided as to why logistic analysis was preferable.

From a statistical point of view, logit regression seems to fit well the characteristics of the default prediction problem, where the dependant variable is binary (default/non-default) and with the groups being discrete, non-overlapping and identifiable. The logit model yields a score between zero and one which

¹⁰ MDA is based on two restrictive assumptions: 1) the independent variables included in the model are multivariate normally distributed; 2) the group dispersion matrices (or variance-covariance matrices) are equal across the failing and the non-failing group. See Barnes (1982), Karels and Prakash (1987) and McLeay and Omar (2000) for further discussions about this topic.

¹¹ Zmijewski (1984) was the pioneer in applying probit analysis to predict default, but, until now, logit analysis has given better results in this field.

conveniently gives the probability of default of the client¹². Lastly, the estimated coefficients can be interpreted separately as the importance or significance of each of the independent variables in the explanation of the estimated PD. After the work of Ohlson (1980), most of the academic literature (Zavgren (1983), Gentry et al. (1985), Keasey and Watson (1987), Aziz et al. (1988), Platt and Platt (1990), Ooghe et al. (1995), Mossman et al. (1998), Charitou and Trigeorgis (2002), Lizal (2002), Becchetti and Sierra (2002)) used logit models to predict default. Despite the theoretic differences between MDA and logit analysis, studies (see for example Lo (1985)) show that empirical results are quite similar in terms of classification accuracy. Indeed, after careful consideration of the nature of the problems and of the purpose of this study, we have decided to choose the logistic regression as an appropriate statistical technique. For comparison purposes, however, we also analyze results using MDA.

2.2 SME studies

More recently, the new Basel Accord for bank capital adequacy (Basel II) has seen many analysts focus on the SME segment (see for example Schwaiger (2002), Saurina and Trucharte (2004), Udell (2004), Berger (2004), Jacobson et al. (2004), and Altman and Sabato (2005)). Actually, criticisms have been raised by governments and SME associations that high capital charges for SMEs could lead to credit rationing of small firms and, given the importance of these firms in the economy, could reduce economic growth. The aforementioned studies have dealt with the problem of the possible effects of Basel II on bank capital requirements, but the problem of modeling credit risk specifically for SMEs has either not been addressed or only briefly considered. Other authors have focused on the difficulties and the potentials of small business lending, investigating the key drivers of SME

¹² Critics of the logit technique, including one of the authors of this paper, have pointed out the specific functional form of a logit regression can lead to bimodal (very low or very high) classification and probabilities of default.

profitability and riskiness for US banks (Kolari and Shin (2004)) or the lending structures and strategies (Berger and Udell (2004)). Recently, Berger and Frame (2005) have analyzed the potential effects of the small business credit scoring on credit availability. They find that banking organizations that implement automated decision systems (such as scoring systems) increase small business credit availability. They focus on micro business credits (up to \$250,000) that were managed with credit scoring from the latter half of 1990s in the US using personal credit history of the principal owner provided by one or more of the consumer credit bureaus (e.g. Equifax, Experian, FICO). However, today banks need to be able to manage as retail clients SMEs with an annual turnover up to at least €1 million (if they want to consider the Basel II definition) to be competitive in the credit business¹³. We think that, excluding self employed and sole trader micro business, the complexity of the other bigger companies cannot be managed only with bureau information, but a financial analysis is needed.

Following the works of a large number of authors (including Kolari and Shin (2004) and Berger (2004)), we conclude that small business lending has a strong positive effect on bank profitability. But we find, in contrast with Kolari and Shin (2004), that lending to SMEs is riskier than to large corporates (see also Saurina and Trucharte (2004), Dietsch and Petey (2004)). As a consequence, we demonstrate that banks should develop credit risk models specifically addressed to SMEs in order to minimize their expected and unexpected losses. Many banks and consulting companies already follow this practice of separating large corporates from small and medium sized companies when modeling credit risk. But, the academic literature lacks a definitive study that demonstrates the significant benefits of such a choice¹⁴. The Edmister (1972) study had focused only on the selection of the financial ratios that can be useful in predicting SME failure. It did

¹³ We are aware of some large, international banks (such as Barclays) that are managing SMEs as retail clients using automated scoring systems for credits up to €3 million.

¹⁴ Bradbury (1992) analyzes the same problem and reaches our same conclusion, i.e. SMEs need specific models different from the large corporate ones. However, he uses a small matched sample containing 40 New Zealand SMEs with a very small size (average total assets about €100.000).

not explain why small firms should be separated from large companies. The emphasis on SME credits in today's environment is far more prominent and we show that modeling specific SME credit risk systems is likely, under certain sceneries, to lead to lower capital requirements when the new Basel Capital Accord will be implemented in 2008¹⁵.

3. SME model development

This Section develops a specific model to estimate one-year SME probability of default. We illustrate the steps of our analysis and compare the results obtained using different statistical instruments (such as log transformations of the variables). Statistical details about the developed models can be found in the Appendixes.

3.1 The data set

The statistical analysis utilizes a sample containing financial data for 2,010 US SMEs with sales less than \$65 million (approximately €50 million), gathered from WRDS COMPUSTAT database over the period 1994-2002. To create this sample, we first assess the number of defaulted firms contained in the COMPUSTAT database during the selected period and we find 120 defaulted SMEs (with non-missing data)¹⁶. Then, we randomly select non-defaulted firms over the same period in order to obtain an average default rate in our sample as close as possible to the expected average default rate for US SMEs (6 percent)¹⁷. We use this expected average default rate as a prior probability input in our

¹⁵ A recent directive extended the introduction in the US one year beyond 2007; 2007 is still the expected implementation date in Europe.

¹⁶ "TL" footnote is used to indicate firms in bankruptcy, while "AG" means that the firm is in reorganization.

¹⁷ This expected average default rate for US SMEs has been suggested to us from a Moody's study about small and medium sized firms in the US, "Moody's KMV Riskcalc v3.1 Model", (2004).

retrospective analysis¹⁸. For each selected year, we calculate the number of non-defaulted SMEs in order to maintain the overall average expected default rate. Subsequently, we randomly select, for each year, the number of non-defaulted firms shown in the third column of Table 1. The total of 120 defaults and 1,890 non-defaults are shown at the bottom of that table. In order to provide a picture of small and medium sized enterprises contained in our sample, Figures 1 and 2 show the distribution of their sales and total assets. Note that SMEs might be somewhat arbitrarily classified as either small or medium sized firms using either sales or assets as the size criteria.

¹⁸ See McFadden (1973) and King and Zeng (2001) for a comprehensive analysis of the use of the prior probability in the logit model.

Table 1. Construction of the data set for the US SMEs

This table shows the construction of the data sample for the US SMEs for the period 1994-2002. In the first column, the different years are depicted. In the second column, the number of the defaulted companies found in the COMPUSTAT database is shown. In the third column, the number of non-defaulted companies, given a default rate of 6 percent, is calculated. In the fourth column, the total number of small and medium sized companies to be selected for each year is shown.

Year	# Defaults	# Non-defaults	Total sample
1994	6	95	101
1995	10	158	168
1996	16	252	268
1997	17	268	285
1998	13	205	218
1999	9	142	151
2000	15	236	251
2001	20	315	335
2002	14	221	235
Total	120	1890	2010

Figure 1. Distribution of sales in the US SME sample

This figure shows the percentage of US SMEs contained in each of four sales classes in our sample. The four size classes could be divided into two groups: ones with sales less than \$25 million (small firms) (68.4 percent) and the ones with sales between \$26 and \$65 million (medium firms) (31.6 percent).

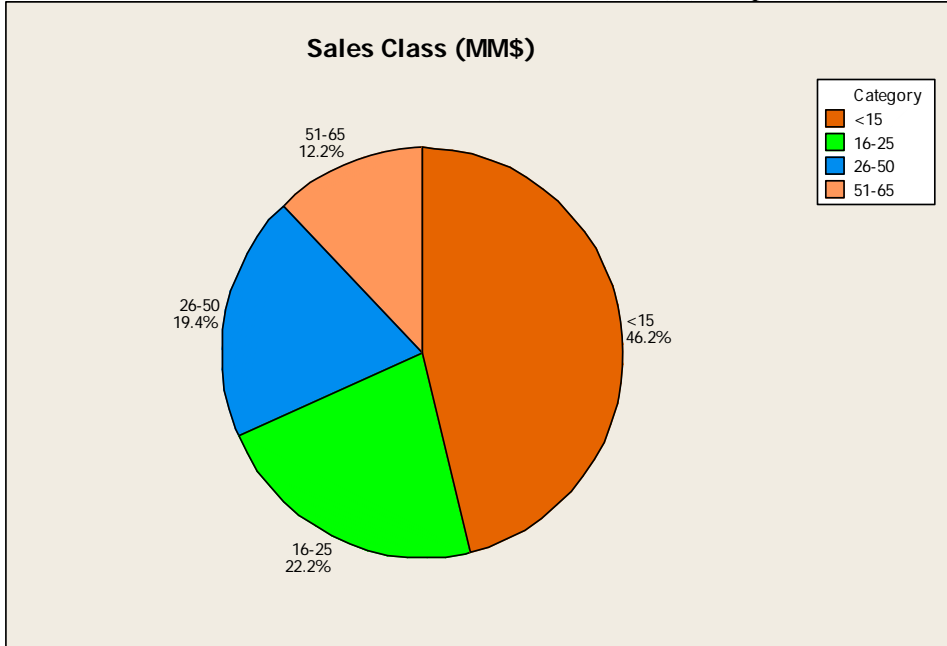
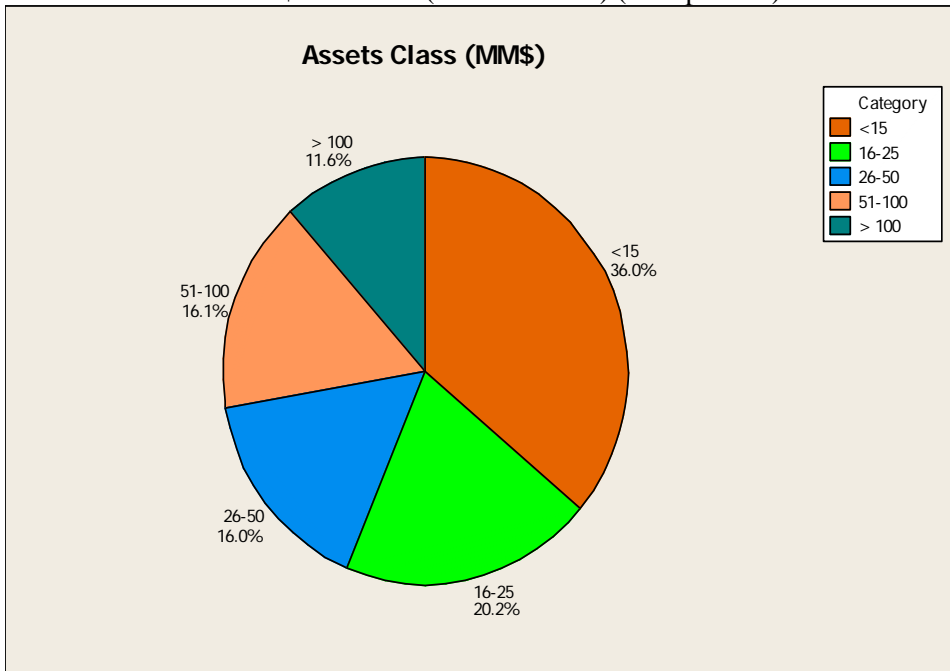


Figure 2. Distribution of assets in the US SME sample

This figure shows the percentage of US SMEs contained in each of five asset classes in our sample. The five asset classes could be divided into two groups: ones with assets less than \$25 million (small firms) (56.2 percent) and the ones with assets more than \$25 million (medium firms) (43.8 percent).



3.2 Selection of the variables

There is a large number of possible candidate ratios identified in the literature as useful to predict firms' default¹⁹. Furthermore, recent literature (e.g. Lehmann (2003) and Grunet et al. (2004)) concludes that quantitative variables are not sufficient to predict SME default and that including qualitative variables (such as the number of employees, the legal form of the business, the region where the main business is carried out, the industry type, etc.) improves the models' prediction power. Notwithstanding this, we are obliged to use only firms' financial statement data since the COMPUSTAT database does not contain qualitative variables²⁰.

Consistent with the large number of studies discussed in Section 2, we choose five accounting ratio categories describing the main aspects of a company's financial profile: liquidity, profitability, leverage, coverage and activity. For each one of these categories, we create a number of financial ratios identified in the literature as being most successful in predicting firms' bankruptcy (see Table 2, first column).

After the potential candidate predictors have been defined and calculated, we observe the accuracy ratio (as defined by Keenan and Sobehart (1999)) for each and arbitrarily select two variables from each group with the highest accuracy. Since this analysis does not take into account the possible correlations between the variables in each group, only two variables were selected from each ratio category rather than one. Next, we apply a statistical forward stepwise selection procedure of the selected ten variables²¹. We then estimate the full model eliminating the least

¹⁹ Chen and Shimerda (1981) show that out of more than 100 financial ratios, almost 50 percent were found useful in at least one empirical study.

²⁰ In a recent work, Zhou et al. (2005) develop a model for North American privately held firms (not only SMEs) using a maximum expected utility (MEU) model. They gather data from S&P's Credit Risk Tracker database, selecting 20 explanatory variables and separating their sample into four relevant groups of industries. The performance of their model is very promising and slightly higher than a model developed using the same variables and a logistic technique. However, we believe that separating the industry groups played an important role in improving the performance of their model (see von Stein and Ziegler (1984) and Keasey and Watson (1987) about the value of integrating qualitative variables into MDA models).

²¹ In some statistical studies, criticism of the forward stepwise selection procedure has been raised as it can yield theoretically implausible models and select irrelevant variables. For this reason, we

helpful covariates, one by one, until all the remaining input variables are efficient, i.e. their significance level is below the chosen critical level. For this study, the significance level is set at 20 percent. Of the ten chosen variables (see Table 2, second column), five variables are selected as doing the best overall job together in the prediction of the SME default (see Table 2, third column). Lastly, observing the default event, we construct the dependent variable, Known Probability of Being Good (KPG), as binary (0=default/1=non-defaulted)²². Actually, we note that the firms considered as defaulted in this study are the ones that went bankrupt under Chapter 11 of the US bankruptcy Code.

Observing the distributions of each of the selected variables for the two dependent variable groups, a large range of values is clearly visible. This high variability of the financial ratios for SMEs can be due either to the different sectors in which these companies operate (real estate firms have financial data completely different from agricultural companies), or to the different ages of the firms in the sample as well as their different level of financial health. We therefore use logarithmic transformations for all of the five selected variables in order to reduce the range of possible values and increase the importance of the information given by each one of them. To prove the effectiveness of this choice, we provide and compare the analyses and the results obtained utilizing the logged and unlogged predictors.

use a two-step analysis, first choosing the most relevant variables for our study and then applying the stepwise selection procedure. See also Hendry and Doornik (1994).

²² We use as dependent variable KPG in order to have positive slopes and intercept since the higher the final logit score is, the higher the probability that the firm will not fail.

Table2. Variables selection process

This table shows how the variables entered in the final model have been selected. In the first column, candidate financial ratios for US SME default prediction are listed. In the second column, the ten financial ratios (two for each accounting ratio category) that presented the highest accuracy between all of the candidate financial ratios are shown. In the third column, the variables entered in the US SME model are listed and grouped by their accounting ratio category.

Variables examined	Variables manually selected	Variables entered in the model	Accounting ratio category
Short Term Debt/Equity (Book Value) Equity (Book Value)/Total Liabilities Liabilities/Total Assets	Short Term Debt/Equity (Book Value) Liabilities/Total Assets	Short Term Debt/Equity Book Value	Leverage
Cash/Total Assets Working Capital/Total Assets Cash/Net sales Intangible/Total Assets	Cash/Total Assets Working Capital/Total Assets	Cash/Total Assets	Liquidity
Ebit/Sales Ebitda/Total Assets Net Income/Total Assets Retained Earnings/Total Assets Net Income/Sales	Ebitda/Total Assets Retained Earnings/Total Assets	Ebitda/Total Assets	Profitability
Ebitda/Interest Expenses Ebit/Interest Expenses	Ebitda/Interest Expenses Ebit/Interest Expenses	Retained Earnings/Total Assets	Coverage
Sales/Total Assets Account Payable/Sales Account Receivable/Liabilities	Sales/Total Assets Account Receivable/Liabilities	Ebitda/Interest Expenses	Activity

3.3 Logistic regression

First, we run the logistic regression using the unlogged variables (a detailed discussion of this model is provided in Appendix A). All of the slopes (signs) follow our expectations (i.e. we expect a positive relationship between the KPG and all the predictors except Short term debt/BV of Equity) and the Wald test for each of the predictors is statistically significant²³. Also the Log-likelihood test is statistically significant, i.e. we can argue that there is a significantly strong relationship between the selected predictors and the default event²⁴. The Hosmer-Lemeshow test (Hosmer and Lemeshow, 1989), which is used to understand whether using an appropriate statistical technique (in this case the logistic regression), is statistically significant (P value equal to 0.421) as we were not making an appropriate choice using the logistic regression. However, the result of the Hosmer-Lemeshow test can be misleading since it can be due only to the wide range of values of the original predictors. Lastly, we observe the measures of association (Somers' "D", Goodman and Kruskal's "Gamma" and Kendall's "Tau-b") to compare this model with the one developed utilizing the logarithmic values of the predictors. We depict our first model in Table 3, where the final score (that can be approximated with the probability that a firm does not default) is given by the sum of the constant (4.28) and the product between the slopes and the value of each of the predictors.

As we will demonstrate, the results (e.g. the accuracy ratio is 75 percent) are accurate, but certainly they could be improved to give us more confidence in the reliability of the model.

²³ The Wald test, described by Polit (1996) and Agresti (1990), is a way to test whether the parameters associated with a group of explanatory variables are zero, or not.

²⁴ The Log-likelihood test is used to understand if all the parameters together are useful to estimate the dependent variable. It is comparable to the multivariate F-Test in the linear regressions (or MDA) and it is also often used to compare the fit of different models (see Dunning 1993).

Table3. Model developed with unlogged predictors

This table shows the model developed using the unlogged values of the variables to predict the probability of the firm being bankrupt (p).

$\text{Log}(PD/1-PD) =$	+	4.28	
	+	0.18	<i>Ebitda/Total Assets</i>
	-	0.01	<i>Short Term Debt/Equity Book Value</i>
	+	0.08	<i>Retained Earnings/Total Assets</i>
	+	0.02	<i>Cash/Total Assets</i>
	+	0.19	<i>Ebitda/Interest Expenses</i>

We then utilize the logarithmic transformed predictors in an attempt to increase the accuracy of the model²⁵. The EBITDA/total assets (EBITDA/TA) and the retained earnings/total assets (RE/TA) variables, following Altman and Rijken (2004), are transformed as follows: $EBITDA/TA \rightarrow -\ln(1-EBITDA/TA)$, $RE/TA \rightarrow -\ln(1-RE/TA)$. Actually, the distributions of these two variables are negatively skewed and the information content in the fat tails of the distribution is relatively low. So, with this transformation we can give more power to the values that are more significant for the regression. Moreover, in this way we partially correct for the trend of the unlogged variables which were continuously drifting down over the years. For example, the RE/TA variable had a mean absolute value in 1980 of almost 20 percentage points higher than the average value for US companies in 2004. The other three variables have the standard log transformation. After these transformations, the regression results look much more promising (see Appendix B for a detailed discussion of this model's development). Wald and Log-likelihood tests are statistically significant as before and the slopes are all reasonable (see Table 4). This time, the Hosmer-Lemeshow test is not statistically significant (P value equal to 0.978). The measures of associations show higher values than before, suggesting that the revised model should have higher prediction accuracy. The accuracy ratio jumped from 75 percent to 87 percent when we transformed each of the original firm variables by using their logarithms. However, to decide if the revised model is really better than the one built with the original predictors, we test and compare their prediction accuracy on a hold-out sample.

²⁵ Bradbury (1988) proves that accounting adjustments made prior to model development do not improve the ability to *ex post* classify loan default. However, this kind of log transformation results in a significantly higher model accuracy.

Table4. Model developed with logged predictors

This table shows the model developed using the logged values of the variables to predict the probability of the firm being bankrupt.

$$\begin{aligned} \text{Log}(PD/1-PD) = & + 53.48 \\ & + 4.09 \text{ } -\text{LN}(1-\text{Ebitda}/\text{Total Assets}) \\ & - 1.13 \text{ } \text{LN}(\text{Short Term Debt}/\text{Equity Book Value}) \\ & + 4.32 \text{ } -\text{LN}(1-\text{Retained Earnings}/\text{Total Assets}) \\ & + 1.84 \text{ } \text{LN}(\text{Cash}/\text{Total Assets}) \\ & + 1.97 \text{ } \text{LN}(\text{Ebitda}/\text{Interest Expenses}) \end{aligned}$$

3.4 Validation results

A holdout sample of 26 bankrupt SMEs for the two-year period 2003-2004 is assembled to test the validation performance of our models²⁶. Then, we randomly select non-bankrupt companies over the same recent two-year period using the methodology explained before. The test sample contains a total of 432 firms (bankrupt and non-bankrupt) with sales less than \$65 million (see Table 5).

Table 6 summarizes the results, in terms of predictive accuracy of the three different models (the two logistic models developed with logged and unlogged predictors and a generic corporate model) tested on the hold-out sample. As generic corporate model, we use the Z''-Score model developed by Altman (1993, 1995 and 2005) (see footnote number 4 for details). The error rates shown in Table 6 are calculated fixing an arbitrary cut-off rate of 30 percent of the population and are quite close to the error rates obtained from the development sample (in the same Table 6, but in brackets)²⁷. Hence, we can argue that the models are statistically robust and valid. We acknowledge that the chosen cut-off rate is possibly not the optimal one since the different misclassification costs for the type I and type II error rates are not taken into account (see Altman et al. (1977) and Taffler (1982)). However, pointedly the purpose of this work is to use a common, arbitrary, fixed cut-off rate only to compare the prediction accuracy of the different models and not to find the best cut-off strategy. Moreover, arguably the optimum cut-off value cannot be found without a careful consideration of each particular bank peculiarities (e.g. tolerance for risk, profit-loss objectives, recovery process costs and efficiency, possible marketing strategies).

²⁶ Again, we use the WRDS COMPUSTAT tapes.

²⁷ Applying the developed model to all the companies contained in the test sample, a score is calculated for each firm. Then, the 30 percent of the sample with the lowest scores is considered rejected in order to check the accuracy of the model to correctly and incorrectly classify the firms (as defaulted and non-defaulted) between accepted and rejected clients. The choice to fix a cut-off at 30 percent is not based on any specific reason; any other percentage could have been chosen for the analysis.

Table 5. Hold-out sample for SMEs

This table shows the structure of the US SME hold-out test sample. In the first and second row, the number and the percentage of non-defaulted and defaulted firms are shown.

	Number	Percentage
Non-defaulted firms	406	94.0%
Defaulted firms	26	6.0%
Total	432	100%

3.5 Comparison of results

In order to compare our results we provide two indexes (columns 4 and 5 in Table 6). The first measures the accuracy of each model in correctly classifying defaulted and non-defaulted firms, as the complement of the weighted average of the type I and type II error rates. The second is called the accuracy ratio (AR) and is defined as the ratio of the area between the cumulative accuracy profile (CAP) of the rating model being validated and the CAP of the random model, and the area between the CAP of the perfect rating model and the CAP of the random model (see Engelman et al. (2003) for further details). Indeed, it measures the ability of the model to maximize the distance between the defaulted and non-defaulted clients.

The overall accuracy level (AR) of our two new logistic models is 75 percent, based on the unlogged variables, and 87 percent based on the logged variables. Most importantly, the type I error is reduced dramatically when we use the logged variables model from over 21 percent to 11.76 percent. Also in Table 6, we compare the holdout results with the popular Z''-Score results built by Altman (1993) to include all industrial firms²⁸. Applying the four variable Z''-Score model to the same holdout sample, we observe an overall accuracy (AR) of 68 percent, compared to the 75 percent for the unlogged new variable model and the 87 percent for the logged structural approach. Again, the biggest improvement between the new model and the generic Z''-Score approach was in the type I accuracy.

²⁸ See footnote number 3 for details about the Z''-Score model.

Table 6. Misclassification rates and accuracy ratios of the different models

This table shows the misclassification rates and the accuracy ratios of the three different models applied to the test sample fixing an arbitrary cut-off rate of 30 percent. The first column shows the type I error rate, i.e. the percentage of defaulted firms classified as non-defaulted. In the second column, the type II error rate is illustrated. This rate represents the percentage of non-defaulted firms classified as defaulted. The third column shows the average accuracy of the model, calculated as 1 minus the average of the two error rates. In the last column, the accuracy ratio, defined as the ratio of the area between the cumulative accuracy profile (CAP) of the rating model being validated and the CAP of the random model, and the area between the CAP of the perfect rating model and the CAP of the random model, is shown. The values in the brackets result from the application of the different models on the development sample.

	Type I error rate	Type II error rate	1- Average Error Rate	Accuracy ratio
Logistic model developed with logarithm transformed predictors	11.76% (9.23%)	27.92% (24.64%)	80.16% (83.07%)	87.22% (89.81%)
Logistic model developed with original predictors	21.63% (20.11%)	29.56% (27.86%)	74.41% (76.02%)	75.43% (77.68%)
Z''-Score Model	25.81% (26.12%)	29.77% (29.52%)	72.21% (72.18%)	68.79% (68.57%)

3.6 Multivariate Discriminant Analysis (MDA)

For comparison purposes, we also run a multivariate discriminant analysis (MDA) model using the same development sample as used for the logistic analysis. In this case, we define two groups maintaining the original number of firms in our sample (1890 non-defaulted firms and 120 defaulted firms). The same five, log transformed financial measures, as the ones selected for the logistic analysis, are utilized as predictors also for MDA. Table 7 shows the model developed with the MDA.

We observe that the ability of this model to separate the two groups is notably lower (see Table 8) than the one developed with the logistic regression (62 percent accuracy ratio versus almost 78 percent and 89 percent measured on the development sample). Moreover, we find that the performance of the MDA model, in terms of maximizing the distance between the two groups (defaulted and non-defaulted firms), is even lower than the performance of the Z''-Score model, developed using MDA, but on data from large corporate firms.

The power of the different financial measures that can be used to predict firms' financial distress is found to be strictly linked to the statistical technique used to develop the prediction model²⁹. In this case, the five financial ratios selected for the logistic analysis do a less accurate overall job together than the five ratios selected by Altman (1993) in his Z''-Score model when MDA is chosen as appropriate statistical technique. Also, in all cases, the ability of MDA models to discriminate between defaulted and non-defaulted firms is lower than logistic models, at least using the same predictors.

²⁹ Our results are in contrast with the conclusion of the Nash et al. (1989) study. They find that prediction of business failure is insensitive to the selection of accounting variables and modeling technique. We believe that these two factors are extremely important to improve the model prediction power.

Table7. MDA model developed with logged predictors

This table shows the model developed using multivariate discriminant analysis to predict the discriminant score (z).

z=	+	15.06	
	+	2.44	<i>-LN(1-Ebitda/Total Assets)</i>
	+	0.91	<i>LN(Short Term Debt/Equity Book Value)</i>
	+	3.90	<i>-LN(1-Retained Earnings/Total Assets)</i>
	+	4.15	<i>LN(Cash/Total Assets)</i>
	+	3.49	<i>LN(Ebitda/Interest Expenses)</i>

Table 8. Misclassification rates and accuracy ratios for MDA methodology

This table shows the misclassification rates and the accuracy ratios of the model developed using MDA methodology applied to the test sample fixing an arbitrary cut-off rate of 30 percent. The first column shows the type I error rate, i.e. the percentage of defaulted firms classified as non-defaulted. In the second column, the type II error rate is illustrated. This rate represents the percentage of non-defaulted firms classified as defaulted. The third column shows the average accuracy of the model, calculated as 1 minus the average of the two error rates. In the last column, the accuracy ratio, defined as the ratio of the area between the cumulative accuracy profile (CAP) of the rating model being validated and the CAP of the random model, and the area between the CAP of the perfect rating model and the CAP of the random model, is shown. The values in the brackets result from the application of the MDA model on the development sample.

	Type I error rate	Type II error rate	1- Average Error Rate	Accuracy ratio
MDA model developed with logarithm transformed predictors	30.12% (29.63%)	29.84% (28.74%)	71.52% (73.32%)	59.87% (62.44%)

4. Basel II capital requirements for SMEs

This Section shows that improving the prediction accuracy of a credit risk model is likely to have beneficial effects on the Basel II capital requirements for SMEs when the Advanced Internal Rating Based (A-IRB) approach is used. Indeed, applying a model with a higher accuracy will result in lower capital requirements regardless if the SMEs are all classified as retail customers or as corporates. The new Basel Capital Accord permits banks the possibility to choose whether to classify firms (with sales less than €50 million and exposure less than €1 million) as *corporate* or as *retail*. But, the Accord also requires that banks manage SMEs on a pooled basis in order to be allowed to consider them as retail customers and to apply the retail formula to calculate their capital requirement³⁰.

The concept of “pool-management” for SMEs is not clearly explained by the Accord and has been the source of some concern for banks. However, arguably the main motivation for the Basel Committee is that many banks, following this requirement, will abandon old forms of relationship management used with SMEs and go towards the use of more efficient automated decision systems (such as scoring and rating systems). Our previous work (Altman and Sabato (2005)), examines the potential issues that banks can face when setting their internal systems and procedures to manage SMEs on a pooled basis and we calculate the potential capital requirements dependent on what proportion of the bank’s SME portfolio is considered as retail or corporate. We conclude that most banks will use a blended approach, classifying a part of the SME portfolio as retail and a part as corporate. As such, we calculate the likely breakeven ratio of retail versus corporate for SME customers.

³⁰ In the US, only large, internationally active banks (core banks) will be required to adopt the A-IRB approach on a mandatory basis, while the other organizations will more than likely remain Basel I banks. This process can create competitive advantages for the biggest banking organizations (see Berger 2004). As such, US regulators are now considering a new type of regulatory capital known as Basel IA, for those banks choosing to not utilize the advanced IRB approach (see Board of Governors of the Federal Reserve, September 30, 2005).

In Pillar 1 of the new Basel Capital Accord, the rules to calculate bank capital requirements for each of the different segments, or “buckets”, are clearly explained. We focus on the formulas that can be used for SMEs when the A-IRB approach is applied. As already stated, banks can classify SMEs as retail, utilizing the formula for “other retail exposures”, or as corporate, applying the corporate formula with the firm-size adjustment³¹. All formulas follow the same calculation steps involving inputs for correlation (R), capital requirement (K) and risk-weighted assets (RWA)³². The most important input variables, to be provided by the banks, are three (PDs, LGDs and exposures at default (EADs)³³), while the asset correlation (R) is implicitly given by the Basel formulas. The exact formulas for SMEs from the final version of the Basel Capital Accord are shown in Table 9. Since, in our data samples, we do not have the loan exposures or the possibility to estimate the LGD for each counterparty, we have to make some assumptions.

This study demonstrates the greater ability of a specific SME credit risk model to separate non-failed from failed firms compared to a generic corporate model (see Tables 10 to 13). We analyze the impact on capital requirements if the entire SME portfolio was considered as *retail* or as *corporate*, respectively. We apply two models (Z’-Score and the newly developed, logistic model specific for SMEs) to our sample to compare results. We are able to create seven rating classes with both models. For each rating class, the probability of default (PD) is calculated by dividing the number of defaults by the total number of enterprises in each class. Rating classes have been created in order to obtain the value of PD closest to the one showed by bond equivalent PD distributions. A fixed loss given default (LGD) of 45 percent is assumed, using the one suggested in the Foundation IRB approach (F-IRB) for senior, unsecured loan exposures, and the percentage of firms in each rating class is used as the weight for the capital requirement (instead

³¹ Basel Committee on Banking Supervision, June 2004, par. 330 and par. 272-273.

³² $RWA = K \times 12.5 \times EAD$. Since the final capital requirement is the 8% of this amount, we do not multiply the RWA by 12.5.

³³ As expressed in par. 334 of the Accord, we assume EAD for on-balance sheet items equal to the loan exposure amount.

Table 9. New SME capital requirement formulas

This table shows the new formulas, the ones contained in the last version (June 2004) of the Basel Accord. For the SMEs classified as retail, the formulas are the ones for the “other retail exposures”. When SMEs are classified as corporate, the formulas to be used are the one for the corporate, considering the size discount. *Source:* Basel Committee on Banking Supervision. 2004. “International Convergence of Capital Measurement and Capital Standards”

SME as retail	SME as corporate
$\text{Correlation}=R=0.03*(1-\text{EXP}(-35*PD))/(1-\text{EXP}(35)) +0.16*[1-(1-\text{EXP}(-35*PD))/(1-\text{EXP}(-35))]$	$\text{Correlation}=R.= 0.12*(1-\text{EXP}(-50*PD))/(1-\text{EXP}(-50)) +0.24*(1-(1-\text{EXP}(-50*PD))/(1-\text{EXP}(-50))) -0.04*(1-(S-5)/45)$
$\text{Capital requirement}=K=\text{LGD}*N((1-R)^{-0.5}*G(PD) +(R/(1-R)^{0.5})*G(0.999)) -PD*\text{LGD}$	$\text{Capital requirement}=K= (\text{LGD}*N((1-R)^{-0.5}*G(PD) +(R/(1-R)^{0.5})*G(0.999))-PD*\text{LGD})*(1-1.5*b)^{-1*(1+(M-2.5)*b)}$ $\text{Maturity adjustment}=(b)= (0.11852-0.05478*\text{LN}(PD)^2)$

of the dollar amount of the loan exposures)³⁴. Classifying all SMEs as *retail*, we obtain a capital requirement of 4.76 percent, using the Z''-Score model, and of 4.31 percent, using the specific model for SMEs (Tables 10 and 13). Both models result in capital requirements considerably below the current 8 percent level, under Basel I.

To consider SMEs as *corporate* (Tables 12 and 13), we have to make two additional assumptions. The first is the effective maturity (M_{eff}). We select possible maturities of three years for smaller firms and five years for medium sized firms. The maturity adjustment ($(b)_{\text{corp.}}$) is a function only of PD. The second assumption is about the amount of sales to use for the size adjustment. We split the SME population into two groups: one with sales between €5 and €25 million (small) and the other with sales between €26 and €50 million (medium). In this way we use an average amount of sales of €10 and €30 million in each size group, respectively³⁵. The two groups' percentages of capital requirements are aggregated, considering their distribution of sales for the two classes (68 percent for small and 32 percent for medium sized firms). The resulting weighted capital requirements of the two size components of SMEs, calculated in Tables 12 and 13, are 8.60 percent ($0.68*8.17+0.32*9.51$), applying the Z''-Score model, and 8.10 percent ($0.68*7.69+0.32*8.98$), applying the new specific model for the SMEs.

The results of this study show that if banks classify their entire SME portfolio as corporate using the A-IRB approach, they will likely face higher capital requirements than under the current Basel I. And, we demonstrate that banks will find this result even if they will apply a specific SME credit risk model with very high prediction accuracy (87 percent in this case). The capital requirement will still

³⁴ We are aware that the assumption that we make about the value of LGD is a strong one. However, we believe that the 45 percent can be considered as an average value for the entire distribution and does not affect our final results. In our previous work (Altman and Sabato, 2005), we analyze how sensitive are the empirical results to our LGD assumption using a sensitivity analysis and we find that our results are confirmed also utilizing different LGD values.

³⁵ These average amounts are based on the realistic assumption that each sales distribution is skewed with more relatively small borrowers than relatively large borrowers (see also Altman and Sabato, 2005).

show a value (8.10 percent), slightly higher than the current 8 percent. Of course, it is possible that an even more accurate SME model could be developed resulting in a capital requirement slightly lower than the current 8 percent. In any case, capital requirements are considerably lower the greater the percentage of a bank's SME portfolio that can be classified as retail customers, but it may not be possible for some banks to classify a large proportion as retail. Also, in all cases, the better the credit scoring model, the lower the capital requirements.

Table 10. Capital requirements for all SMEs as retail applying the Z''-Score model

This table shows the capital requirement when all SMEs are classified as retail. In the first column, rating classes have been assigned on the bond equivalent basis. In the second and third column, probability of default (PD) and loss given default (LGD) are shown. In the fourth column, the correlation for each rating class is calculated using the formula: $R_{sme} = \text{Correlation} = 0.03 * (1 - \text{EXP}(-35 * \text{PD})) / (1 - \text{EXP}(-35)) + 0.16 * [1 - (1 - \text{EXP}(-35 * \text{PD})) / (1 - \text{EXP}(-35))]$. In the fifth column, the capital requirement linked to each rating class is calculated with the following formula: $K_{sme} = \text{Capital requirement} = \text{LGD} * N((1 - R)^{-0.5}) * G(\text{PD}) + (R / (1 - R)^{0.5}) * G(0.999) - \text{PD} * \text{LGD}$. In the sixth column, the weights are assigned utilizing the percent of firms in each rating class. In the last column, the product of the capital requirement (K_{sme}) and the weight is cumulated to obtain the total capital requirement.

Rating	PD	LGD	R_{sme}	K_{sme}	Weight	Cum. Weighted K_{sme}
AAA	0.03%	45%	0.15864	0.0035609	0.0464	0.017%
BBB	0.37%	45%	0.14421	0.0216938	0.0711	0.171%
BB	1.47%	45%	0.10771	0.0424133	0.2730	1.329%
BB-	1.86%	45%	0.09780	0.0455248	0.2979	2.685%
B+	4.73%	45%	0.05483	0.0528520	0.1015	3.221%
B	7.01%	45%	0.04118	0.0554183	0.1000	3.776%
CCC	26.57%	45%	0.03001	0.0889581	0.1100	4.755%

Table 11. Capital requirements for all SMEs as retail applying the new model specific for SMEs

This table shows the capital requirement when all SMEs are classified as retail. In the first column, rating classes have been assigned on the bond equivalent basis. In the second and third column, probability of default (PD) and loss given default (LGD) are shown. In the fourth column, the correlation for each rating class is calculated using the formula: $R_{sme} = \text{Correlation} = 0.03 * (1 - \text{EXP}(-35 * \text{PD})) / (1 - \text{EXP}(-35)) + 0.16 * [1 - (1 - \text{EXP}(-35 * \text{PD})) / (1 - \text{EXP}(-35))]$. In the fifth column, the capital requirement linked to each rating class is calculated with the following formula: $K_{sme} = \text{Capital requirement} = \text{LGD} * N((1 - R)^{-0.5}) * G(\text{PD}) + (R / (1 - R)^{0.5}) * G(0.999) - \text{PD} * \text{LGD}$. In the sixth column, the weights are assigned utilizing the percent of firms in each rating class. In the last column, the product of the capital requirement (K_{sme}) and the weight is cumulated to obtain the total capital requirement.

Rating	PD	LGD	R_{sme}	K_{sme}	Weight	Cum. Weighted K_{sme}
AAA	0.03%	45%	0.15864	0.0035609	0.0618	0.022%
BBB	0.37%	45%	0.14421	0.0216938	0.1727	0.397%
BBB-	0.58%	45%	0.13612	0.0280984	0.1916	0.935%
BB	1.35%	45%	0.11097	0.0412190	0.1993	1.757%
B+	3.92%	45%	0.06295	0.0519062	0.1196	2.378%
B	7.46%	45%	0.03954	0.0560496	0.1083	2.985%
CCC	28.27%	45%	0.03001	0.0905826	0.1467	4.313%

Table 12. Capital requirements for all SMEs as corporate applying the Z''-Score model

This table shows the capital requirement when all SMEs are classified as corporate. In the first column, rating classes have been assigned on the bond equivalent basis. In the second and third column, probability of default (PD) and loss given default (LGD) are shown. In the fourth column, the correlation for each rating class is calculated using the formula: $R_{corp.} = \text{Correlation} = 0.12 * (1 - \text{EXP}(-50 * \text{PD})) / (1 - \text{EXP}(-50)) + 0.24 * (1 - (1 - \text{EXP}(-50 * \text{PD})) / (1 - \text{EXP}(-50))) - 0.04 * (1 - (S - 5) / 45)$, where S is the amount of sales for each firm. In the fifth column, the maturity adjustment is calculated as: $(b)_{corp.} = \text{Maturity adjustment} = (0.11852 - 0.05478 * \text{LN}(\text{PD})^2)$. In the sixth column there is the effective maturity (M_{eff}). In the seventh column, the capital requirement linked to each rating class is calculated with the following formula: $K_{corp.} = \text{Capital requirement} = (\text{LGD} * N((1 - R)^{-0.5} * G(\text{PD}) + (R / (1 - R)^{0.5}) * G(0.999)) - \text{PD} * \text{LGD}) * (1 - 1.5 * b)^{-1 * (1 + (M - 2.5) * b)}$. In the eighth column the weights are assigned utilizing the percent of firms in each rating class. In the last column the product of the capital requirement (K_{sme}) and the weight is cumulated to obtain the total capital requirement.

	Rating	PD	LGD	$R_{corp.}$	$(b)_{corp.}$	$M_{eff.}$	$K_{corp.}$	Weight	Cum. Weighted $K_{corp.}$
Sales €5-25mil	AAA	0.03%	45%	0.20266	0.31683	3.0	0.0103082	0.0464	0.048%
	BBB	0.37%	45%	0.18418	0.18084	3.0	0.0403521	0.0711	0.335%
	BB	1.47%	45%	0.14199	0.12228	3.0	0.0681862	0.2730	2.196%
	BB-	1.86%	45%	0.13179	0.11343	3.0	0.0725625	0.2979	4.358%
	B+	4.73%	45%	0.09572	0.08161	3.0	0.0920618	0.1015	5.292%
	B	7.01%	45%	0.08805	0.06976	3.0	0.1056370	0.1000	6.349%
	CCC	26.57%	45%	0.08444	0.03653	3.0	0.1650145	0.1100	8.165%

	Rating	PD	LGD	$R_{corp.}$	$(b)_{corp.}$	$M_{eff.}$	$K_{corp.}$	Weight	Cum. Weighted $K_{corp.}$
Sales €25-50mil	AAA	0.03%	45%	0.22044	0.31683	5.0	0.0173454	0.0464	0.081%
	BBB	0.37%	45%	0.20195	0.18084	5.0	0.0503980	0.0711	0.439%
	BB	1.47%	45%	0.15976	0.12228	5.0	0.0803944	0.2730	2.634%
	BB-	1.86%	45%	0.14957	0.11343	5.0	0.0852268	0.2979	5.173%
	B+	4.73%	45%	0.11350	0.08161	5.0	0.1075484	0.1015	6.264%
	B	7.01%	45%	0.10583	0.06976	5.0	0.1227498	0.1000	7.492%
	CCC	26.57%	45%	0.10222	0.03653	5.0	0.1833518	0.1100	9.510%

Table 13. Capital requirements for all SMEs as corporate applying the new model specific for SMEs

This table shows the capital requirement when all SMEs are classified as corporate. In the first column, rating classes have been assigned on the bond equivalent basis. In the second and third column, probability of default (PD) and loss given default (LGD) are shown. In the fourth column, the correlation for each rating class is calculated using the formula: $R_{corp.} = \text{Correlation} = 0.12 * (1 - \text{EXP}(-50 * \text{PD})) / (1 - \text{EXP}(-50)) + 0.24 * (1 - (1 - \text{EXP}(-50 * \text{PD})) / (1 - \text{EXP}(-50))) - 0.04 * (1 - (S - 5) / 45)$, where S is the amount of sales for each firm. In the fifth column, the maturity adjustment is calculated as: $(b)_{corp.} = \text{Maturity adjustment} = (0.11852 - 0.05478 * \text{LN}(\text{PD})^2)$. In the sixth column there is the effective maturity (M_{eff}). In the seventh column, the capital requirement linked to each rating class is calculated with the following formula: $K_{corp.} = \text{Capital requirement} = (\text{LGD} * N((1 - R)^{-0.5} * G(\text{PD}) + (R / (1 - R)^{0.5}) * G(0.999)) - \text{PD} * \text{LGD}) * (1 - 1.5 * b)^{-1 * (1 + (M - 2.5) * b)}$. In the eighth column the weights are assigned utilizing the percent of firms in each rating class. In the last column the product of the capital requirement (K_{sme}) and the weight is cumulated to obtain the total capital requirement.

	Rating	PD	LGD	$R_{corp.}$	$(b)_{corp.}$	$M_{eff.}$	$K_{corp.}$	Weight	Cum. Weighted $K_{corp.}$
Sales €- 25mil	AAA	0.03%	45%	0.20266	0.31683	3.0	0.0103082	0.0618	0.064%
	BBB	0.37%	45%	0.18418	0.18084	3.0	0.0403521	0.1727	0.761%
	BBB-	0.58%	45%	0.17424	0.16051	3.0	0.0493287	0.1916	1.706%
	BB	1.35%	45%	0.14546	0.12549	3.0	0.0665925	0.1993	3.033%
	B+	3.92%	45%	0.10133	0.08758	3.0	0.0871829	0.1196	4.076%
	B	7.46%	45%	0.08732	0.06796	3.0	0.1082527	0.1083	5.249%
	CCC	28.27%	45%	0.08444	0.03524	3.0	0.1662226	0.1467	7.686%

	Rating	PD	LGD	$R_{corp.}$	$(b)_{corp.}$	$M_{eff.}$	$K_{corp.}$	Weight	Cum. Weighted $K_{corp.}$
Sales €25-50mil	AAA	0.03%	45%	0.22044	0.31683	5.0	0.0173454	0.0618	0.107%
	BBB	0.37%	45%	0.20195	0.18084	5.0	0.0503980	0.1727	0.977%
	BBB-	0.58%	45%	0.19201	0.16051	5.0	0.0600597	0.1916	2.128%
	BB	1.35%	45%	0.16324	0.12549	5.0	0.0786535	0.1993	3.696%
	B+	3.92%	45%	0.11911	0.08758	5.0	0.1019516	0.1196	4.916%
	B	7.46%	45%	0.10510	0.06796	5.0	0.1256196	0.1083	6.276%
	CCC	28.27%	45%	0.10222	0.03524	5.0	0.1842301	0.1467	8.978%

5. Conclusions

We have investigated whether banks should separate small and medium sized firms from large corporates when they are setting their credit risk systems and strategies. The findings demonstrate that managing credit risk for SMEs requires models and procedures specifically focused on the SME segment. We improve upon the existing literature in various ways.

First, we use, for the first time, the definition of SME provided by the new Basel Capital Accord (sales less than \$65 million) that will become relevant for banks in about two years, when Basel II will be in force. Gathering data on US SMEs, we analyze a complete set of financial ratios exploring carefully their characteristics.

Second, by utilizing well-known statistical techniques, five financial ratios are found in combination to be the best predictors of SME default and we use them to develop a credit risk model specific for SMEs. This model is used as an instrument to show, on a hold-out sample, the different performance of a specific SME model versus a generic corporate model (Z' -Score model). Results strongly confirm our expectations. The performance, in terms of prediction accuracy, of our specific SME model is almost 30 percent higher than the performance of the generic corporate model. Indeed, we demonstrate that banks will likely enjoy significant benefits in terms of SME business profitability by modeling credit risk for SMEs separately from large corporates. Also MDA default prediction models are demonstrated as likely to have a lower ability to discriminate between defaulted and non-defaulted clients than logistic models when the same variables are used as predictors.

Last, we show that modeling credit risk specifically for SMEs also results in slightly lower capital requirements (around 0.5 percent) for banks under the A-IRB approach of Basel II than applying a generic corporate model. This is true whatever the percentage of SME firms classified as retail or as corporates. This is due to the

higher discrimination power of a specific SME credit risk model applied on a SME sample.

Our findings also confirm, to some extent, what has been found in the other studies: i.e., that small and medium sized enterprises are significantly different from large corporates from a credit risk point of view. However, we demonstrate that banks should not only apply different procedures (in the application and behavioral process) to manage SMEs compared to large corporate firms, but these organizations should also use instruments, such as scoring and rating systems, specifically addressed to the SME portfolio. Thus, banks should carefully consider the results of this study when setting their internal systems and procedures to manage credit risk for SMEs.

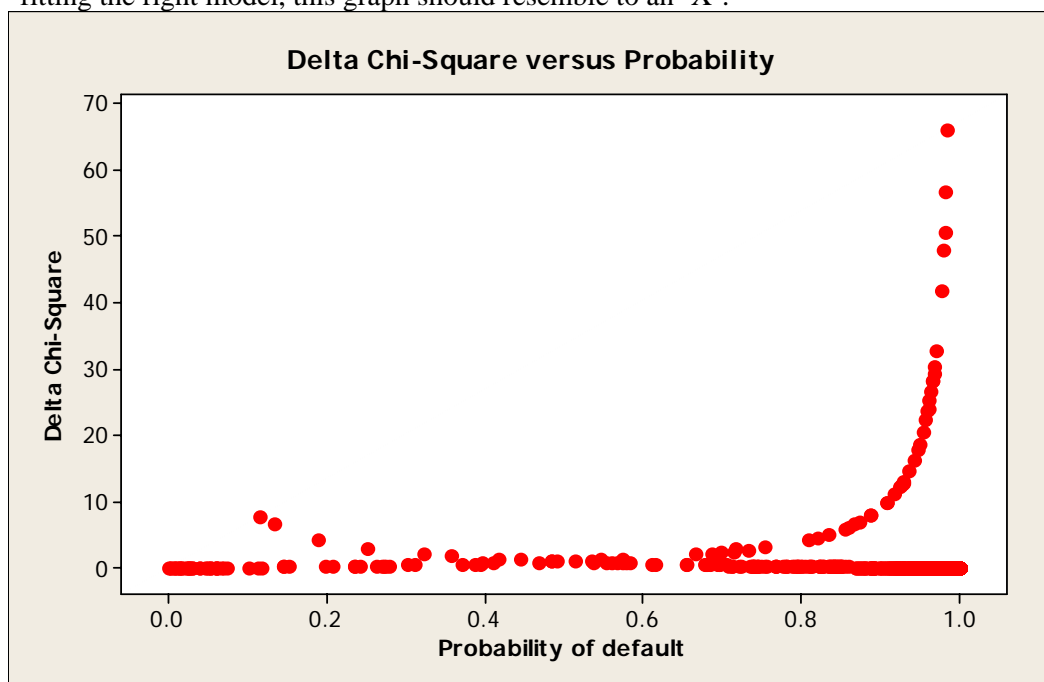
Appendix A: Logistic Regression with original Predictors

First, we run a logistic regression using the original value of the predictors. The following variables entered in the regression: EBITDA/total assets, short term debt/equity book value, retained earnings/total assets, cash/total assets and EBITDA/interest expenses.

As a diagnostic plot, we observe the delta chi-square versus probability of default. This graph shows an approximation of the square of residuals versus fitted values. The closer the resemblance to an 'X', the more confident we can be that we are fitting the right model.

Figure B-1. Diagnostic plot of Delta chi-square versus probability of default

This figure shows an approximation of the square residuals versus fitted values. When fitting the right model, this graph should resemble to an 'X'.



Observing this plot and taking into account the result of the Hosmer-Lemeshow test, we can be reasonably sure that this is not the optimal model. The high variability of the financial ratios is likely to play a strong role in this result; hence we need to reduce this large range of possible values, for example by using a logarithmic transformation of the predictors.

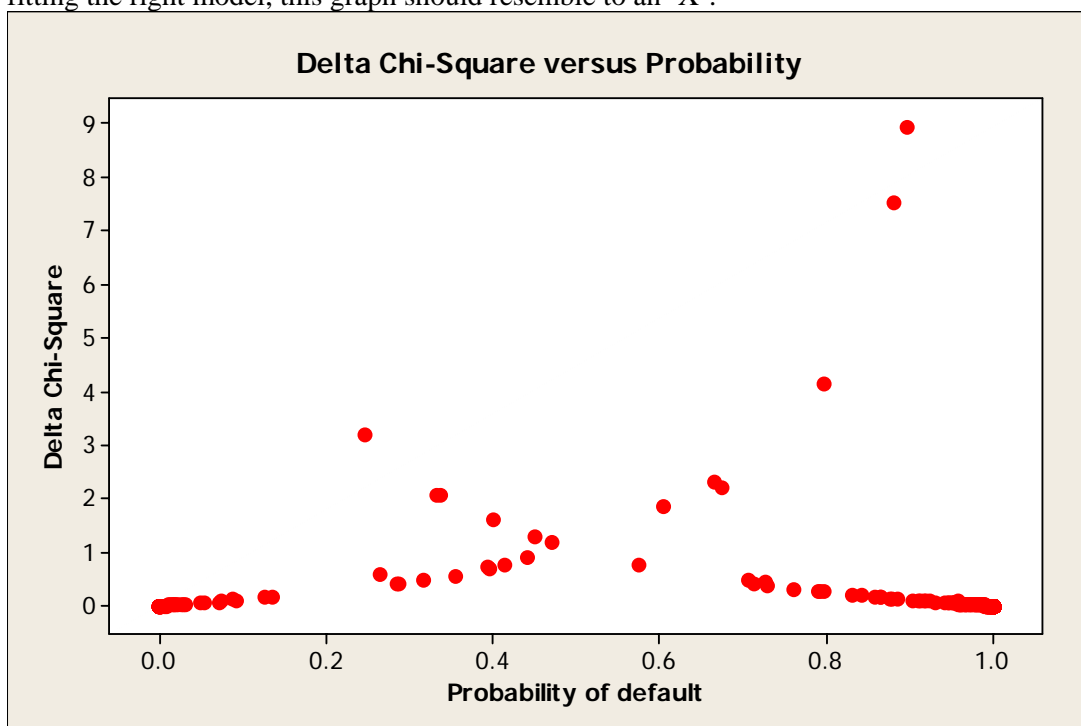
Appendix B: Logistic Regression with Logarithmic Transformed Predictors

We run a logistic regression using the logarithmic transformed value of the predictors. The following variables entered in the regression: EBITDA/total assets, short term debt/equity book value, retained earnings/total assets, cash/total assets and EBITDA/interest expenses. In order to increase the effectiveness of the EBITDA/total assets (EBITDA/TA) and the retained earnings/total assets (RE/TA) variables, these variables are log-transformed as follows: $EBITDA/TA \rightarrow -\ln(1-EBITDA/TA)$, $RE/TA \rightarrow -\ln(1-RE/TA)$.

We observe the delta chi-square versus probability of default, as diagnostic plot.

Figure C-1. Diagnostic plot of Delta chi-square versus probability of default

This figure shows an approximation of the square residuals versus fitted values. When fitting the right model, this graph should resemble to an 'X'.



This plot confirms the result of the Hosmer-Lemeshow test. Observing the measures of association, we can also argue that the performance of this model will be higher (as we indeed find).

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