contribution to default prediction in the presence of DD. Of course, whether this assertion holds in practice is subject to empirical investigation.[18]

Since a time series of default flags along with their covariates are observed for each issuer, we are dealing with time-series cross-sectional data, also called panel data or longitudinal data. In this setting, a pooled logit regression approach, in which the error terms e_{it} are assumed to be conditionally independent across both firms and over time, is not appropriate. It is reasonable to expect nonzero serial correlation in the error terms between time series observations of a given firm. One way to deal with "intra-class" serial correlation is to decompose the error term e_{it} into two components

$$e_{it} = u_i + v_{it} \quad (2)$$

where u_i captures the unobserved firm-specific heterogeneity that may raise or reduce the overall level of a firm's probability of default but are not included in x_{it}, and v_{it} denotes the "true" noise that are conditionally independent both across firms and over time. Note that this approach further lessens the need to include other covariates in the regression, as the firm-specific error term will absorb any additional variance (which, again, we are not specifically concerned with in this paper).

Given the presence of unobserved firm-specific effects, there are generally two approaches to estimation of *β*, fixed effects (FE) estimation and random effects (RE) estimation. The key distinction between the two approaches is whether the unobserved effect u_i is assumed to be independent of the covariates x_{it} for all *t*.[19] Under the RE approach to panel logit regression, it is assumed that $u_i \mid x \sim N(0,\sigma_u^2)$, so that u_i and x_i are independent. This means, in the context of a default prediction model, that firm-specific characteristics that may affect the level of a firm's PD but which are not included in x_i are uncorrelated with x_{it} for all *t*. This assumption is reasonable when DD1 is included in x_i, since DD1 is a sufficient statistic to default probability in structural models. However, when equity returns are the sole covariate of the logit regression, variables excluded from x_{it} are likely to be correlated with x_i (e.g. accounting ratios are likely correlated with equity returns).[20] In the absence of other covariates, RE estimation would not be an appropriate approach in this case. By contrast, FE estimation allows the unobserved effect to be arbitrarily correlated with variables included in x_i. So FE estimation is a suitable approach when equity returns are the sole regressor of the panel logit regression.[21]

We estimate five models using DD1 and equity returns as regressors: fixed and random effects models using equity returns and DD1 alone (respectively); a pooled logit model on both covariates; a generalized estimating equations (GEE model) with the same regression specification as the pooled logit model but robust standard errors; and a random effects model that includes both DD1 and equity returns. The last regression deserves the most attention as it provides that answer to the question we are trying to answer in this section.

18 Some contradicting evidence has been documented by researchers using their versions of Merton-type structural models. Hillegeist, Keating, Cram, and Lundstedt (2004) show in a discrete duration model that their version of distance to default does not entirely explain variation in default probabilities across firms. Campbell, Hilscher, and Szilagyi (2005) also find that distance to default does not produce a sufficient statistic for the probability of default in the presence of market leverage and volatility information, among other covariates.

19 Traditionally, random effects are distinguished from fixed effects estimation by the fact the unobserved firm-specific heterogeneity term is treated as a random intercept in RE approach, whereas in FE approach, it is explicitly estimated as a firm-specific parameter. In this study, we adopt a modern view of the distinction: The firm-specific heterogeneity term is treated as a random variable sampled from the population along with other covariates. What distinguishes the two estimation methods is essentially the correlation assumption between the unobserved effect and the covariates. See Wooldridge (2001).

20 A large body of financial research in the field of asset pricing is concentrated on the task of searching for risk variables (or proxies of them) which can be used to predict/explain variations in equity returns. A partial list of these studies can easily exceed dozens of pages. In this default prediction study, it is quite logical to believe that these risk variables may help increase default prediction power of equity returns and at the same time are highly correlated with equity returns,

21 The FE estimation to panel logit model is also called conditional logit model since the number of default observations for each issuer is conditioned out in forming the joint likelihood function.

logistic form. When the error structure is assumed to be homoscedastic and serially uncorrelated, the GEE approach is essentially the same as the pooled logit regression. However, one can make inference of the coefficient estimates in the GEE model using Huber-White type robust standard errors. The coefficient estimates under the GEE approach (Model 4 of **Figure 9**) are identical to those of the pooled logit regression (Model 3). But with robust standard error estimates, only the coefficient for DD1 remains statistically significant.

In Model 5, both DD1 and equity returns are included as covariates in the panel logit RE estimation. We argue that this is an appropriate estimation approach because it allows serial correlation in composite errors between repeated observations of the same firm and it is reasonable to assume zero correlation between unobserved firm-specific effects and DD1 in structural credit risk models. Therefore, the estimation results are amenable to proper interpretation. The coefficient for DD1 is less than unity and remains statistically significant, implying a negative relationship between DD1 (and EDFs) and the odds ratio of default. However, the coefficient for equity returns is very close to one, and we cannot reject the null hypothesis by looking at its z-statistic that equity returns provides no additional power to default prediction in the presence of DD1. This conclusion is consistent with the two-dimensional portfolio evidence, where the realized default rate monotonically increases with EDFs but exhibits smirk-shaped variation over the dimension of equity returns.

Overall, the RE panel logit regression presents a compelling case that EDFs are superior to equity returns as warning signals of default risk, when the error structure of the logit regression is properly accounted for. Although equity returns exhibit default predictive power when they are used as the sole covariate (consistent with their moderate accuracy ratio), they provide little additional explanatory power in the presence of DD1.

Conclusion

Equity prices are an important input in deriving Moody's public firm EDF™ credit measures. If one has access to a firm's equity price history, does he/she still need a signal derived from a structural credit risk model such as EDFs in assessing the firm's default risk? In light of evidence from this study, the answer is yes, except for the very limited situations where the firm's imminent default risk is readily reflected in its precipitously declining stock prices.

The empirical evidence presented in this paper shows that there is a weak direct link between equity returns and default risk. Unlike EDFs, equity returns do not properly rank order firms' default risk. As expected, very poor stock performance is indicative of high default risk. However, very good stock performance is also, on average, followed by relatively high default rates. As a result, the widely assumed link between low equity performance and high default risk is actually rather weak. In addition, to the extent that EDFs represent the true, unobservable default rates, there is substantial variation in default risk among firms with similar past stock performances. This is true even for subsets of firms whose equity performance, on average, lines up properly with their EDFs. So equity returns may not only provide misleading directions in discriminating defaulters from non-defaulters for firms with moderate to good stock performances, they are also very noisy in the sense that firms with similar stock performances report both very high and very low EDFs.

Not surprisingly, the overall power of default prediction by equity returns is much lower than that by EDFs, as measured by their accuracy ratios. This is not to say that equity returns have no predictive power at all. But their performance is generally inferior to EDFs. Another weakness of using equity returns as default warning signals is that the resulting accuracy ratios exhibit wide swings over time, rendering its default predictive power very unreliable. The superior predictive power of EDFs relative to equity returns is most striking when EDFs and equity returns cast opposite views of firms' default risk. In this situation, the average default rate of firms viewed as most default risky by their EDFs, but least default risky by their equity returns, is 16 times higher than firms located in the opposite end of the risk spectrum, i.e., most risky viewed by equity returns but least risky by EDFs. By pitting EDFs against equity returns in logit-type regressions, we show formally in a statistical sense that equity returns contribute no additional default predictive power in the presence of EDFs.

We argue that the lack of monotonic relationship between equity returns and EDFs (as well as realized default rates) is a manifestation of directionally distinct information incorporated in the two measures. In particular, the derivation of EDFs relies on both the risk assessment of a firm's underlying business and the firm's capital structure, as well as its equity prices. The results of this study provide another demonstration that the first two inputs into EDFs' calculation, i.e., business risk assessment and capital structure, are critical in improving their default predictive power.

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