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Book-to-Market Equity, Asset Correlations and the Basel Capital Requirement

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Abstract: This paper examines the effect of book-to-market equity (BE/ME) on asset correlations under the Basel capital requirement. We find that BE/ME captures variations in asset correlations after controlling for firm size, default probability and industry effects from 1987 to 2011. Obligors with higher BE/ME exhibit lower asset correlations compared to those with lower BE/ME. Decomposing BE/ME into assets-in-place and growth options based on the asset pricing literature shows that obligors with more assets-in-place or more fixed assets have higher BE/ME and lower asset correlations than those with more growth options. Overall, our findings suggest that BE/ME is an additional important factor that may improve the estimates of asset correlations and thereby banks' capital adequacy.

Keywords: bank capital requirement, asset correlation, book-to-market equity, firm size, default probability

1. INTRODUCTION

Asset correlation, which measures the co-movement between a borrower's asset returns and the common risk factor that summarizes general economic conditions, is a key parameter in determining a bank's minimum capital requirement under the Basel II Accord. A higher asset correlation for the borrower implies a higher systematic risk to the lender (i.e., the bank), which then means that the bank is required to hold more capital. Under the current regulatory capital requirement, asset correlations are conditioned on the borrower's firm size and default probability. For example, asset correlation is a decreasing function of default probability, and there is a size adjustment factor for small and medium sized enterprises (SMEs) in the asset correlation function.

In addition to firm size and default probability, we explore the potential effect of another well known firm characteristic, book-to-market equity (BE/ME), on asset

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correlations. The importance of BE/ME for pricing equity has been well documented by Fama and French (1992, 1993) in the asset pricing literature. Since then, the Fama and French three-factor model, which includes market factor, BE/ME and firm size, has become the standard empirical asset pricing model for estimating risk-adjusted equity returns in a variety of applications in the accounting and finance literature. Using non-US data, Chen and Chui (1996) and Artmann et al. (2012) show that BE/ME is robust in explaining average stock returns in the UK and Germany, respectively. Accordingly, BE/ME, which can be viewed as a source of systematic risk, may relate to asset correlations in the same way in which market factor and firm size explain the behavior of asset correlations in the Basel framework.

If BE/ME is important in capturing variations in asset correlations, then the current specifications on capital adequacy requirement can be improved by incorporating BE/ME as an additional determinant of asset correlations. More specifically, banks with obligors having higher BE/ME should be required to hold a different level of capital than those having lower BE/ME. Such an implementation of the Basel capital requirement may potentially reduce regulatory arbitrage under the presence of conditioning asset correlations by BE/ME.[1]

Our investigation into the relationship between asset correlations and BE/ME may also shed more light on the underlying sources of BE/ME – a central issue in the asset pricing literature. On the one hand, efficient market believers argue that BE/ME is a proxy for systematic risk. Fama and French (1992) first present that firms with high BE/ME tend to experience poor past earnings and are said to be more financially distressed. Lev and Sougiannis (1999) find that the BE/ME effect is a proxy for the R&D effect generated by a firm's R&D capital. They argue that it can represent an extra market risk factor inherent in R&D. Closely related to the systematic risk argument, Clubb and Naffi (2007) explain that expected returns can be explained by expected ROE and expected change in BE/ME, which is an accounting identity when the clean surplus relationship holds for accounting earnings. Their findings are therefore consistent with fundamental valuation or rational pricing.

Behaviorists argue, on the other hand, that the BE/ME effect is driven by mispricing. Debondt and Thaler (1985), Lakonishok et al. (1994) and Antoniou et al. (2006) note that investors tend to overreact to past information. Therefore, firms with poor past earnings growth or high BE/ME tend to have higher future returns. Similarly, Brouwer et al. (1997), Cai (1997) and Gregory et al. (2001), who respectively examine European, Japanese and the UK stock markets, conclude that the BE/ME effect cannot be explained by risk differences alone. Campbell et al. (2008) further show that although distressed firms are related to higher BE/ME, they deliver lower returns. It follows that the BE/ME effect is not driven by financial distress as suggested by Fama and French (1992), because firms with higher BE/ME are related to higher returns. They offer that the results are inconsistent with rational asset pricing models. Given the current debate on the BE/ME effect, our findings on the relationship between BE/ME and asset correlations, and the BE/ME effect in the presence of firm size and default probability should add further understanding to the issue.

1 Regulatory arbitrage may occur when the risk of assets is not properly priced, thereby providing incentives for banks to engage in riskier assets without the requirement for additional capital. In our context, banks may generate riskier loans characterized by obligors with a lower BE/ME relative to those with a higher BE/ME under the Basel capital requirement, which does not consider BE/ME to be a systematic risk factor.

Drawn from a sample of 65,301 firm-year observations from 1987 to 2011, we find that BE/ME explains average asset correlations. Our results are as follows. First, firms with high (low) BE/ME have lower (higher) asset correlations after controlling for firm size, firm default probability and industry effects. It suggests that BE/ME captures additional variations in asset correlations that the current factors do not account for. Although market equity may not be readily observable for obligors that are not publicly traded (e.g., SMEs), the proportion of fixed assets to total assets in these firms may serve as a good measure for BE/ME as evidenced in the relationship between BE/ME and operating leverage.

For further analysis on the importance of BE/ME, we follow Daniel and Titman (2006) and Fama and French (2008) by decomposing BE/ME into three components: past BE/ME, changes in book equity and changes in market equity. They suggest that in the decomposition, changes in book equity can be viewed as a proxy for the change in the value of assets-in-place, while changes in market equity can be explained as a proxy for change in the value of growth options. As the former is positively related to operating leverage and the latter is negatively related to operating leverage, these two components should have opposite effects on asset correlations.

Consistent with the theoretical construct on the decomposition, we find that asset correlations vary negatively with changes in book equity, but positively with changes in market equity. The observed relationships indicate that an increase in assets-in-place (proxied by an increase in book equity) is related to lower asset correlations, whereas a similar increase in growth options (proxied by an increase in market equity) is related to higher asset correlations. Taking these two opposing effects together, it demonstrates that a high (low) BE/ME obligor, which has more (less) value of assets-in-place than the value of growth options, exhibits lower (higher) asset correlations.

Second, we find that asset correlations vary negatively with firm default probability, but vary positively with firm size – that is, larger firms and lower default probability firms are likely to be subject to greater systematic risk. Our results are therefore consistent with Lopez (2004) and Chernich et al. (2006), but not with Duellmann and Scheule (2003), Dietsch and Petey (2004), Kupiec (2009) or Lee et al. (2009) who report that asset correlations are higher on average for firms with higher default probability. Our evidence hence supports the specifications of asset correlations in the current ASRF framework in relation to firm size and firm default probability.

Firm characteristics such as firm size and firm default probability (i.e., financial leverage) affect asset correlations, because they capture different dimensions of a firm's systematic risk. Lopez (2004) and Dietsch and Petey (2004) show that firm size varies positively with asset correlations, because large firms are more diversified and are thus more sensitive to common risk factors than firm-specific factors. On the other hand, Lopez (2004), Das et al. (2006) and Chernich et al. (2006) suggest that firms with higher default probability exhibit higher idiosyncratic risk relative to systematic risk. As a result, it varies negatively with asset correlations.

Third, asset correlations appear to be industry-specific, independently from the firm size effect. We find that firms across industries with similar levels of asset correlations differ in average firm size. These results contradict Düllmann and Scheule (2003) and Chan et al. (2007), who suggest that the size effect may possibly be driven by the industry effect.

The remainder of this study is organized as follows. Section 2 discusses the potential linkages between BE/ME and operating leverage. Section 3 provides an overview of banks' capital adequacy requirement and the determinants of asset correlations. Section 4 outlines the methodology of estimating asset correlations. Sections 5 and 6 respectively present the descriptive statistics of our data and empirical results. Section 7 concludes the paper.

2. POTENTIAL RELATIONSHIP BETWEEN BE/ME AND OPERATING LEVERAGE

Ever since Hamada (1972), who first lays out the theoretical foundation between the positive relationship between financial leverage and the systematic risk of a firm's equity, there has been ongoing research into the impact of leverage on systematic risk. Lev (1974) extends the relationship of systematic risk to operating leverage. Mandelker and Rhee (1984) sum up a firm's systematic risk in terms of its business risk, risk of financial leverage and risk of operating leverage. Accordingly, the importance of leverage may not just be limited to financial leverage, which relates firm default probability to asset correlations.

In light of the pioneering work of Berk et al. (1999), who contend that a firm's investment activities rather than its financing activities are potentially a source of the BE/ME effect, a number of theoretical models explicitly link a firm's operating leverage to BE/ME. For example, when operating costs are assumed to be fixed and proportional to production capacity, Carlson et al. (2004) and Cooper (2006) show that firms with higher BE/ME (more assets-in-place relative to growth options) are less responsive to negative aggregate demand shocks. By measuring operating leverage as the average sensitivity of the percentage deviation of EBIT relative to the percentage deviation of sales, Garcia-Feijoo and Jorgensen (2010) find that BE/ME is positively related to operating leverage, which is in turn positively related to systematic risk.

In a similar vein, Zhang (2005) shows that assets-in-place are riskier than growth options in economic downturns when the price of risk is high and disinvestment is costly. He further argues that growth options are not necessarily riskier in economic upturns, because increases in investment are relatively less costly. Combining the varying effects through business cycles suggests that firms with more assets-in-place are subject to higher systematic risk. Consistent with Zhang (2005), Li et al. (2009) find that value firms (high BE/ME) correlate positively with time-varying volatility, which is in turn related to the business cycle.

By assuming that production costs are variable and not proportional to the installed capacity, Aguerrevere (2009) argues that operating leverage is lower than previously suggested, because firms can reduce output to lower costs when demand falls (or during economic downturns). This real option to reduce capacity utilization as demand falls plays a crucial role in lowering operating leverage when firm value is low. As a result, firms with a high book-to-market ratio have lower operating leverage. Consistent with Aguerrevere (2009), Xing and Zhang (2004), who estimate operating leverage as the elasticity of operating profits with respect to sales, report that value firms (with high BE/ME) exhibit lower operating leverage than growth firms (with lower BE/ME).

Firms are more likely to invest when demand is high (or during economic upturns). The expected increase in production capacity is likely to reduce the effect of demand shocks on the value of assets-in-place, thereby reducing firms' risk. It explains why firms with more assets-in-place (high BE/ME) are less risky than those with more growth options (low BE/ME) when demand is high. Furthermore, the value of growth options is likely to be more sensitive to changes in demand during economic upturns, because the investment cost for additional capacity can be viewed as the leverage for growth options.

Taking together the time-varying sensitivities of assets-in-place and growth options to changes in economic conditions, Aguerrevere (2009) suggests that the operating leverage for firms with more growth options (or lower BE/ME) is higher than for those with more assets-in-place (or higher BE/ME). In other words, the risk of growth options when demand is high may outweigh that of assets-in-places when demand is low. Hence, low BE/ME may be related to higher systematic risk.

From the fundamental valuation perspective, Ohlson (1995) operationalizes the dividend discount model by transforming firm value as a function of book value, residual income and "other information". Known as the residual income valuation model, it postulates that firm value can be derived from the current book value of assets and the present value of anticipated residual income due to future profitability. The former can be viewed as assets-in-place and the latter as growth options. Firms that derive most of their value from their book value should have high BE/ME, whereas those that derive most of their value from discounted residual income have low BE/ME. Since discounted residual income, like growth options, is more sensitive to changes in economic conditions than the book value of assets, firms with high BE/ME should exhibit lower asset correlations.

3. THE BASEL II ACCORD AND THE DETERMINANTS OF ASSET CORRELATIONS

(i) The Role of Asset Correlations in Basel II

The Basel Committee on Banking Supervision (BCBS) permits banks to choose between two broad approaches for determining their capital requirements in relation to the estimates of credit risk. One alternative is the standardized approach, an extension of the original Basel Accord, whereby regulatory capital requirements are based on a common set of risk parameters for assessing credit risk. The other is known as the internal rating-based (IRB) approach, which allows banks to internally assess an individual borrower's possible credit losses.

To ensure that capital requirements properly reflect material systematic risk, X, in credit losses over time and guarantee sufficient capital to cover losses especially during adverse circumstances ($X = x_{99.9}$), IRB banks are required to calculate credit risk in terms of their conditional expected loss (CEL) and unexpected loss:

$$CEL = P[D = 1|X = x_{99.9}] \times E[L|D = 1, X = x_{99.9}], \tag{1}$$

where $P[D = 1|X = x_{99.9}]$ is the conditional probability of default (CPD) and $E[L|D = 1, X = x_{99.9}]$ is the conditional loss given default (CLGD) on the 0.1% level. Here, D is an indicator variable that equals one if a default occurs, and zero otherwise. For estimating CPD, Basel II uses the Asymptotic Single Risk Factor (ASRF) approach developed by Gordy (2003):

$$CPD = N\left(\frac{N^{-1}(PD) + \sqrt{\rho} \cdot N^{-1}(0.999)}{\sqrt{1-\rho}}\right), \tag{2}$$

where $N(\cdot)$ is the standard normal cumulative density function, $N^{-1}(\cdot)$ is the inverse of this function, PD is the probability of default, and ρ is the asset correlation. Accordingly, correlations in realized losses across exposures are assumed to be driven by a single systematic risk factor capturing the effects of unexpected changes in economic conditions. The loss rate for a well-diversified credit portfolio therefore depends only on the systematic risk factor rather than the idiosyncratic risk factors associated with individual exposures.

Although asset correlation is defined as the correlation between an asset return and a market return, obtaining each individual asset correlation is largely impractical. As a result, Basel II provides different weights for borrower types to calculate asset correlations. For example, for corporate loans (Basel II 2006 draft), the asset correlation estimation is:

$$\begin{aligned}\rho(PD) &= 0.12\left(\frac{1-e^{-50*PD}}{1-e^{-50}}\right) + 0.24\left(1-\frac{1-e^{-50*PD}}{1-e^{-50}}\right)\\ &= 0.24 - 0.12\left(\frac{1-e^{-50*PD}}{1-e^{-50}}\right),\end{aligned} \tag{3}$$

where PD is the probability of default. Equation 3 implies a negative relationship between asset correlation and default probability – that is, a firm with higher PD corresponds to a lower asset correlation. Consistent with the specification in equation 3, Düllmann and Scheule (2003) contend that as the credit risk of a firm increases, firm-specific risk factors become relatively more important than systematic risk. Since default probability varies inversely with business cycles, it is important to note that the negative relationship between asset correlation and default probability lessens the procyclicality of the regulatory capital requirement.

(ii) The Effect of Default Probability, Firm Size and Industry on Asset Correlations

Under Basel II's specifications, asset correlations are negatively related to default probability. Obligors with higher default probability are assigned lower asset correlations. Consistent with the Basel II accord, Lopez (2004) and Chernich et al. (2006) show that average asset correlations are negatively related to default probability. Equally important, the negative relationship between average asset correlation and default probability is more pronounced for larger firms, implying that larger firms are also related to higher asset correlations.

Servigny and Renault (2002) show, however, that asset correlations are higher for non-investment grade firms than for investment grade firms. Kupiec (2009) also present that asset correlations are greater for lower-quality credits. Nickell et al. (2000) report that volatility increases sharply in economic downturns for low-graded obligors, implying a higher correlation with the systematic factor. Lee et al. (2009) find that asset correlations for commercial real estate and retail exposures vary positively with default probability, because sub-prime borrowers are more sensitive to business cycles.

Dietsch and Petey (2004) show that, after controlling for firm size, the asset correlations of SMEs are no longer negatively related to default probability. In fact, they report that the relationship turns positive after removing the size effect. They also suggest that a different risk-weight function should apply for SMEs as their estimated correlations are significantly lower than those provided by the Basel Committee.

In another conjecture, Düllmann and Scheule (2003) suggest that the size effect may be related to the industry effect. They reason that industries that are more sensitive to the cyclical effect are those in which firm concentrations are high. For example, manufacturing, construction and automotive sectors that tend to be more cyclical comprise a smaller percentage of SMEs. Consistent with the argument, Chan et al. (2007) find that return correlations are higher for large stocks of the same industries than those of their counterparts of other industries. The co-movement in returns among smaller stocks within the same industries is, at the same time, less pronounced. These findings suggest the industry effect may be proxied by firm size.

4. DEFAULT PROBABILITY AND ASSET CORRELATION ESTIMATION

To estimate default probability, we apply the structural model of Merton (1974) that treats the value of equity as a European call option written on the underlying assets of a firm. The market value of a firm's equity E therefore can be expressed as:

$$E = VN(d_1) - e^{-rT}DN(d_2), \tag{4}$$

where V is the value of a firm's assets, D is the level of debt at maturity time T, $d_1 = \frac{\ln(\frac{V}{D})+(r+\frac{\sigma_A^2}{2})(T)}{\sigma_A\sqrt{T}}$, $d_2 = d_1 - \sigma_A\sqrt{T}$, r is the risk-free interest rate, σ_A is the standard deviation of a firm's asset returns, and $N(\cdot)$ is the cumulative standard normal distribution. It is important to note that $N(-d_2)$ measures a firm's default probability. Since the default probability measure relies on the risk-neutral assumption in the Merton model, we replace the risk-free interest rate with the instantaneous expected return on the firm's assets (μ_A) in order to calculate default probability under an objective probability measure.

Based on the ASRF framework, Lee et al. (2011) and Lee and Lin (2012) show that asset correlation ρ_A can be estimated as follows:

$$\rho_A = \left(\frac{Cov(r_A, r_M)}{\sigma_A\sigma_M}\right)^2 = \left(\frac{\beta_E}{N(d_1)}\frac{E}{V}\frac{\sigma_M}{\sigma_A}\right)^2, \tag{5}$$

where $Cov(r_A, r_M)$ is the covariance between asset returns r_A and market returns r_M, σ_M is the standard deviation of the market returns, and β_E is the equity beta. Since both V and σ_A in equation 5 are unobservable, Lee et al. (2011) and Lee and Lin (2012) use the asset volatility equation implied by the Merton model, $\sigma_E = \frac{V}{E}N(d_1)\sigma_A$, to estimate V and σ_A.

Crosbie and Bohn (2003) point out, however, that the market leverage (i.e., E/V) in the asset volatility model linking equity and asset volatility moves around far too much to provide a reasonable estimate of σ_A. More specifically, asset volatility tends to be overestimated (underestimated) when the market leverage is decreasing (increasing), resulting in a biased estimator. Furthermore, the relationship between asset correlations and BE/ME can be mechanically driven by construction via leverage.

For example, an increase in the market value of equity leads to a higher E/V and thus higher asset correlations, but lower BE/ME. As a result, asset correlations are negatively related to BE/ME.

To solve this problem, we follow Crosbie and Bohn (2003), Vassalou and Xing (2004), and Bharath and Shumway (2008) for measuring asset returns and standard deviations. First, we introduce an initial value of $\sigma_A = \left[E/(E+D) \right] \sigma_E$ and use this value of σ_A and equation 4 to infer the daily market value of each firm's assets for the previous year. This therefore generates a time-series of daily asset returns. We next use the daily asset return series to generate new estimates of σ_A by iterating on σ_A until it converges (so the absolute difference in adjacent σ_A is less than 10^{-3}). We also obtain the drift term, μ_A, from the daily asset return series. Finally, we calculate the covariance between asset return and market return in equation 5 before solving for asset correlations.[2]

5. DATA

We obtain our sample of US firms from COMPUSTAT and the Center for Research in Securities Prices (CRSP) for the period 1987 to 2011. We exclude banks in order to focus on the asset correlations of corporate borrowers. We also exclude firms with missing or no liabilities. All of the variables are winsorized at 1% and 99% to minimize the impact of outliers in the asset correlation distribution. We set the maturity date to one year and use the one-month T-bill rate as a proxy for the risk-free rate. The market index is value-weighted from the AMEX/ NYSE/ NASDAQ composite indices.

Our final sample includes 65,301 firm-year observations taken over 25 years, covering firms in 9 industrial sectors. They include Energy, Materials, Industrials, Consumer Discretionary, Consumer Staples, Health Care, Information Technology, Telecommunication Services and Utilities. Each sector is further divided into industry groups based on global industry classification (GICS) codes. Table 1 classifies and reports a total of 20 industry groups.

Table 2 presents the summary statistics of the sample firms over a period from 1987 to 2011. The average asset value of the sample firms is US$ 1.61 billion, ranging widely from US$ 2.17 million to US$ 45.1 billion. A large difference between the mean and median of asset values indicates that the distribution is skewed towards a few very large firms. This is not surprising since it is well known that large firms tend to make up most of the total market capitalization in a stock market. It follows that liabilities, equity and sales of the sample firms exhibit similar variability as do the asset values. Our estimated asset correlations also vary widely between 0.00 and 0.83 with an average of 0.10. In sum, the variability of the sample estimates of asset correlations, BE/ME, default probability and firm size allows us to examine the relationships among them.

6. EMPIRICAL RESULTS

(i) Firm Default Probability, Size and BE/ME Effects

We begin the empirical analysis on the effect of firm default probability and firm size on asset correlations. As discussed earlier in section 2, evidence on the relationship

2 We thank the journal referee for suggesting this estimation method.

Table 1
Industry Classification, Industry Size and Asset Correlations

Code	*Sector*	*Sub-code*	*Industry Group*	*Sales ($million)*	*Average AC*
10	Energy	1010	Energy	1,785	0.106
15	Materials	1510	Materials	1,841	0.120
20	Industrials	2010	Capital Goods	1,431	0.116
		2020	Commercial & Professional Services	650	0.081
		2030	Transportation	1,869	0.115
25	Consumer Discretionary	2510	Automobiles and Components	2,158	0.094
		2520	Consumer Durables and Apparel	955	0.080
		2530	Consumer Services	742	0.090
		2540	Media	1,093	0.098
		2550	Retailing	1,640	0.089
30	Consumer Staples	3010	Food and Staples Retailing	4,466	0.089
		3020	Food, Beverage and Tobacco	2,562	0.089
		3030	Household & Personal Products	1,573	0.083
35	Health Care	3510	Health Care Equipment and Services	566	0.069
		3520	Pharmaceuticals, Biotechnology and Life Sciences	761	0.104
45	Information Technology	4510	Software and Services	565	0.098
		4520	Technology Hardware & Equipment	1,072	0.091
		4530	Semiconductors and Semiconductor Equipment	866	0.176
50	Telecommunication Services	5010	Telecommunication Services	2,092	0.120
55	Utilities	5510	Utilities	1,752	0.123

Notes:
This table presents 20 industrial groups according to the Global Industry Classification Standard (GICS) code, average sales (in US$ million) of the industries and average asset correlations (AC) over the sample period from 1987–2011.

between firm default probability and asset correlations is mixed and may also be confounded by the size effect. To examine if a consistent relationship exists between the explanatory variables and asset correlations, we first double sort the sample firms according to firm default probability and firm size and then calculate the average asset correlation for each group.

Table 2
Summary Statistics of the Sample Firms from 1987 to 2011

	Mean	*S.D.*	*Max*	*Q3*	*Median*	*Q1*	*Min*	*N*
Market Value of Assets (US$ million)	1,610.84	4,013.19	45,104.58	1,157.75	228.26	53.08	2.17	65,301
Total Liabilities (US$ million)	428.17	1,172.99	12,642.00	264.00	37.40	5.55	0.02	65,301
Market Value of Equity (US$ million)	1,198.53	3,236.37	34,830.90	783.46	162.23	36.44	1.26	65,301
Sales (US$ million)	1,340.81	3,385.91	37,990.00	981.84	213.20	48.36	0.10	65,301
Book-to-Market Equity	0.64	0.54	3.64	0.83	0.52	0.30	0.00	65,301
Default Probability	0.03	0.08	0.84	0.01	0.00	0.00	0.00	65,301
Volatility of Asset Returns	0.44	0.28	1.65	0.58	0.36	0.23	0.04	65,301
Asset Correlations	0.10	0.14	0.83	0.14	0.04	0.01	0.00	65,301

Note:
This table presents the average values of market equity, volatility of equity returns, total liabilities, market value of assets, volatility of asset returns, sales, book-to-market equity, default probability and asset correlations of the sample firms from 1987 to 2011.

Table 3
Average Asset Correlations Sorted by Book-to-market Equity, Default Probability and Firm Size from 1987 to 2011

	Size/PD	*Low*		*Medium*		*High*	
Small	Low BE/ME	0.066	0.083	0.055	0.064	0.029	0.033
	Medium BE/ME		0.065		0.058		0.034
	High BE/ME		0.040		0.037		0.023
Medium	Low BE/ME	0.139	0.158	0.124	0.131	0.070	0.077
	Medium BE/ME		0.137		0.127		0.083
	High BE/ME		0.113		0.103		0.062
Big	Low BE/ME	0.214	0.232	0.174	0.176	0.083	0.085
	Medium BE/ME		0.208		0.170		0.089
	High BE/ME		0.181		0.157		0.078

Notes:
This table presents the average asset correlations based on default probability and firm size for each year from 1987 to 2011. Each firm is sorted by firm size into small, medium and big portfolios. The firm is then independently sorted by default probability into low, medium and high portfolios. An average asset correlation is calculated for each of the nine sub-portfolios for each year.

Table 3 shows that firms with low default probability (*PD*) are characterized by higher asset correlations than firms of high default probability after controlling for firm size. This negative relationship is robust for each size group (i.e., small, medium and big) over the sample period. These preliminary results appear to be inconsistent with Dietsch and Petey (2004), who report that asset correlations are positively related to default probability for SMEs after removing the size effect. It is interesting to note that the impact of firm default probability is particularly pronounced for big firms where the difference in asset correlations between low default probability and high default probability is substantial. For example, the average asset correlation of 0.214 for big firms in the low default probability group is more than twice that of 0.083 for those in the high default probability group.

Controlling for firm default probability, we find that bigger firms have higher asset correlations than smaller firms. The observed positive relationship persists across each default probability group (i.e., low, medium and high). In general, there appears to be a monotonic relationship between asset correlations and firm size. However, the difference in asset correlations between small and big firms seems larger in the low default probability group. In particular, firm size becomes more influential on asset correlations when firms exhibit low probability of default.

To examine the relationship between BE/ME and asset correlations in the presence of firm size and default probability, we further subdivide each size portfolio into terciles according to BE/ME. Table 3 shows that firms with low BE/ME are likely to have higher asset correlations than firms with high BE/ME after controlling for size and default probability. For each of the 9 sub-portfolios sorted by size and default probability, we find that firms with low BE/ME exhibit higher asset correlations than those with high BE/ME. The effect of BE/ME is therefore likely to be different from the effects of size and default probability.

(ii) Industry Effect

To investigate whether the industry effect, if any, on asset correlations is proxied by firm size, we first assign each sample firm to one of the 20 industries according to its global industry classification standard (GICS) code. For each industry group, we then calculate the average asset correlations and firm size over the sample period.[3]

As shown in Table 3, there appears to be no certain relationship between average firm size and average asset correlations – that is, larger firms on average exhibit both high and low asset correlations just as do smaller firms. For example, the asset correlations of firms with large average sales in Food and Staples Retailing and in Automobiles and Components are 0.089 and 0.094, respectively. However, the asset correlations of firms with smaller average sales in Commercial and Professional Services and in Software and Services are similar at 0.081 and 0.098, respectively. A correlation coefficient of –0.007 between average industry size and asset correlations suggests that the industry effect differs from the firm size effect on asset correlations. The summary statistics thus far cast doubt on the possible linkage between size and industry effects.

(iii) Regression Results

Following the preliminary results of firm size, firm default probability, BE/ME, and industry effects, we estimate equation 6 to test if BE/ME captures additional variations in asset correlations:

3 The results remain similar when we use either equity value or asset value as a proxy for firm size.

$$AC_{i,t} = \alpha + b_1 \ln(BE_{i,t}/ME_{i,t}) + b_2 PD_{i,t} + b_3 LnSales_{i,t} + \sum_{j=1}^{19} \gamma_j DI_j + \sum_{k=1}^{24} \delta_k DY_k + \varepsilon_{i,t}, \quad (6)$$

where $AC_{i,t}$ is the asset correlation for firm i at time t, $\ln(BE_{i,t}/ME_{i,t})$ is the natural log of book equity to market equity, $PD_{i,t}$ is the default probability, $LnSales_{i,t}$ is the natural log of the firm sales proxy for firm size, DI_j is the industry dummy for industry j, DY_k is the dummy variable for year k, and $\varepsilon_{i,t}$ is the error term. We include the annual dummy variable to control for the time fixed effect. For a robustness check on the regression results, we transform asset correlations using the inverse logistic function, $ILnAC = Ln(AC/(1-AC))$, which allows the dependent variable to vary beyond the restricted range of zero to one.

Panels A and B of Table 4 present the regression results of various effects on asset correlations. Consistent with our earlier results, column 1 in Panel A shows that BE/ME alone is significantly and negatively related to average asset correlations. Firms with higher BE/ME are likely to be associated with lower asset correlations than firms with lower BE/ME. Columns 2 and 3 also show that asset correlations are a negative function of default probability and a positive function of firm size.

Adding default probability and firm size along with BE/ME in columns 4 and 5 presents little influence on the importance of BE/ME on asset correlations. Here, BE/ME continues to explain average asset correlations that firm default probability and firm size fail to account for. To check whether the BE/ME effect may be proxied by the industry effect, we control the industry effect by adding industry dummies in column 7. Again, the significance of the BE/ME effect is unaffected by the presence of all other variables. These results in Panel A are also robust to the inverse logistic function of asset correlations reported in Panel B. In sum, they confirm that incorporating BE/ME as a factor helps to capture additional variations in average asset correlations. Our results thus far are consistent with Aguerrevere (2009) who demonstrates in his model that BE/ME is negatively related to systematic risk.

Results in Table 4 also suggest that the effect of default probability is different from the size effect. Incorporating firm size does not alter the effect of default probability on asset correlations, because the coefficients of default probability in column 6 are largely insensitive to the presence of firm size. Most importantly, the effects of default probability and firm size on asset correlations are consistent with the specifications in the current ASRF framework.

Consistent with the preliminary results, the size effect is found to be unrelated to the industry effect. Including industry dummy variables in column 7 does not change the relationship between firm size and asset correlations. While not tabulated in Table 4, we find that more than half of the industries explain average asset correlations at the 5% significance level. Similar to the results reported in Table 3, asset correlations for the industry groups of media, information technology and telecommunication service are higher than average (positive dummy coefficients), while those for the industry groups of retailing and consumer staples are lower than average (negative dummy coefficients).

Table 4
Regression Results of Book-to-market Equity, Default Probability and Size Effect

	1	*2*	*3*	*4*	*5*	*6*	*7*
Panel A: Dependent Variable: AC							
Intercept	0.385***	0.401***	0.219***	0.389***	0.201***	0.207***	0.199***
	(135.34)	(142.35)	(79.42)	(138.56)	(73.96)	(75.82)	(61.93)
Ln(BE/ME)	−0.022***			−0.019***	−0.025***	−0.023***	−0.022***
	(−41.68)			(−35.96)	(−55.41)	(−52.19)	(−48.76)
PD		−0.265***		−0.237***		−0.089***	−0.078***
		(−47.65)		(−42.69)		(−18.20)	(−16.00)
Ln(Sales)			0.027***		0.028***	0.027***	0.028***
			(147.00)		(152.81)	(146.17)	(146.64)
Industry dummy							Yes
Year dummy	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Adj.R^2	0.40	0.40	0.54	0.42	0.56	0.56	0.58
Panel B: Dependent Variable: Iln(AC)							
Intercept	−1.136***	−0.741***	−4.354***	−1.015***	−4.789***	−4.472***	−4.823***
	(−19.88)	(−13.36)	(−77.58)	(−18.42)	(−87.50)	(−82.57)	(−75.88)
Ln(BE/ME)	−0.527***			−0.430***	−0.586***	−0.521***	−0.463***
	(−50.41)			(−42.23)	(−65.23)	(−58.42)	(−50.76)
PD		−8.144***		−7.506***		−4.698***	−4.469***
		(−74.30)		(−68.76)		(−48.18)	(−46.37)
Ln(Sales)			0.537***		0.547***	0.511***	0.553***
			(142.81)		(150.24)	(139.76)	(145.17)
Industry dummy							Yes
Year dummy	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Adj.R^2	0.23	0.26	0.39	0.28	0.43	0.45	0.47
N	63,327	63,327	63,327	63,327	63,327	63,327	63,327

Notes:
This table presents the regression results of asset correlations on book-to-market equity, default probability and firm size from 1987 to 2011. Ln(*BE/ME*) is the natural log of book-to-market equity, *PD* is default probability, Ln(*Sales*) is the natural log of sales for firm size, industry dummy takes the value of 1 for a given industry, and 0 otherwise, and year dummy takes the value of 1 for a given year, and 0 otherwise. *t*-statistics are reported in parentheses. *** denotes statistical significance at the 1% level.

(iv) Decomposing the BE/ME Effect

As discussed in section 2, BE/ME contains information about a firm's operating leverage determined by the proportion of its firm value from assets-in-place and growth options. Unlike Lee and Lin (2012) who show that the sources of BE/ME can be derived from net operating assets and financial leverage, we decompose BE/ME into assets-in-place and growth options for further insights. Based on the Daniel and Titman (2006) and Fama and French (2008) approach, we decompose BE/ME into prior BE/ME, the change in book equity, and the change in market equity. Algebraically, $Ln(BE_t/ME_t)$ can be expressed as follows:

$$Ln(BE_t/ME_t) = Ln(BE_{t-1}/ME_{t-1}) + Ln(BE_t/BE_{t-1}) - Ln(ME_t/ME_{t-1}), \qquad (7)$$

where $Ln(BE_{t-1}/ME_{t-1})$ is the past BE/ME at $t-1$ or past information about a firm's systematic risk related to BE/ME, $Ln(BE_t/BE_{t-1})$ is the change in book equity from $t-1$ to t and can be viewed as a proxy for the change in value of assets-in-place, and $Ln(ME_t/ME_{t-1})$ is the change in market equity from $t-1$ to t or the change in value of growth options. By disentangling the change in value of assets-in-place and the change in value of growth options embedded in BE/ME, we can examine their individual impact on asset correlations as follows:

$$\begin{aligned} AC_{i,t} = \alpha + b_1 Ln(BE_{i,t-1}/ME_{i,t-1}) + b_2 Ln(BE_{i,t}/BE_{i,t-1}) + b_3 Ln(ME_{i,t}/ME_{i,t-1}) \\ + b_4 PD_{i,t} + b_5 LnSales_{i,t} + \sum_{j=1}^{19} \gamma_j DI_j + \sum_{k=1}^{24} \delta_k DY_k + \varepsilon_{i,t} \qquad (8) \end{aligned}$$

Columns 1 and 2 of Table 5 respectively report the results of asset correlations and their inverse logistic function according to equation 8. Past BE/ME at $t-1$ remains influential, just as for its contemporaneous term, in explaining average asset correlations. Firms with higher past BE/ME exhibit lower asset correlations than firms with lower past BE/ME. In fact, the economic significance of the past BE/ME is the largest among the three decomposed BE/ME components that does not diminish over time. This empirical observation is consistent with the notion that a firm's systematic risk related to BE/ME does not change quickly.

Table 5 further shows that an increase in the value of assets-in-place ($Ln(BE_t/BE_{t-1})$) lowers a firm's asset correlations. Again, our results are consistent with Aguerrevere (2009) and Xing and Zhang (2004) who find that firms with high BE/ME have lower operating leverage. It implies that a firm with more tangible assets is characterized by relatively higher firm-specific risk or lower systematic risk. This line of argument runs parallel to a firm with higher default probability that is also characterized by relatively higher firm-specific risk or lower systematic risk. It follows that firms with a higher default probability or a greater value of assets-in-place exhibit lower asset correlations.

The value of growth options ($Ln(ME_t/ME_{t-1})$) is, by contrast, positively related to asset correlations. A firm that has a greater proportion of firm value generated from growth options tends to be characterized by higher asset correlations. Again, the results support Aguerrevere (2009)'s model, which demonstrates that growth options are more risky, because the investment cost for growth opportunities in good times

Table 5
Regression Results of Default Probability, Firm Size and Industry Effect

Dependent Variable	*1*	*2*
AC	Yes	
ILn*AC*		Yes
Independent variable		
Intercept	0.200***	−4.815***
	(61.85)	(−75.61)
Ln[*BE*(*t*−1)/*ME*(*t*−1)]	−0.028***	−0.550***
	(−53.90)	(−53.73)
Ln[*BE*(*t*)/*BE*(*t*−1)]	−0.015***	−0.231***
	(−17.87)	(−13.55)
Ln[*ME*(*t*)/*ME*(*t*−1)]	0.018***	0.411***
	(24.85)	(28.56)
PD	−0.056***	−4.016***
	(−11.19)	(−40.81)
Ln(*Sales*)	0.029***	0.556***
	(146.41)	(144.91)
Industry dummy	YES	YES
Year dummy	YES	YES
Adj.R^2	0.58	0.48
N	64,149	64,149

Notes:
This table presents the regression results of asset correlations on book-to-market equity components, default probability and firm size from 1987 to 2011. *BE*(*t*) is the book equity at year *t*, *ME*(*t*) is the market equity at year *t*, *PD* is default probability, Ln(*Sales*) is the natural log of sales for firm size, industry dummy takes the value of 1 for a given industry, and 0 otherwise, and year dummy takes the value of 1 for a given year, and 0 otherwise. *t*-statistics are reported in parentheses. *** denotes statistical significance at the 1% level.

behaves as a leverage that increases the correlation between a firm's returns and the market returns.

The opposing effects from the value of assets-in-place and the value of growth options on asset correlations embedded in BE/ME overall explain why BE/ME is negatively related to asset correlations. A high BE/ME firm with a higher value of assets-in-place lowers asset correlations just as a low BE/ME with a higher value of growth options increases asset correlations.

7. CONCLUSIONS

In the spirit of the Basel Accord and in accordance with the ASRF framework, we examine if BE/ME – an important factor in explaining a firm's equity return – is also influential on asset correlations. Our empirical analysis suggests that BE/ME plays an important role in asset correlations where obligors with higher (lower) BE/ME are related to lower (higher) asset correlations.

We trace the sources of the BE/ME effect by disentangling the individual effects embedded in BE/ME into three components: past BE/ME, the change in the value of assets-in-place and the change in the value of growth options. We find that asset correlations are negatively related to the change in the value of assets-in-place and positively related to the change in growth options. Therefore, firms with a higher value of assets-in-place (growth options) and therefore higher (lower) BE/ME exhibit lower (higher) asset correlations. These linkages offer a better understanding of why BE/ME and asset correlations are negatively related.

Our results have important implications for the Basel capital requirement. First, conditioning asset correlations on BE/ME in addition to size and default probability should improve banks' capital adequacy, which is an important regulatory concern in the aftermath of the global financial crisis. Accordingly, banks with low BE/ME obligors should hold more capital than those with high BE/ME obligors since the former exhibit higher systematic risk than the latter. More specifically, regulators should impose different weights on asset correlations based on obligors' BE/ME in addition to different weights for obligors' size and default probability. In other words, obligors with lower (higher) BE/ME should be assigned with higher (lower) asset correlations.

Second, incorporating BE/ME as a systematic risk factor in asset correlations helps to reduce the procyclical impact of capital requirement – one of the main regulatory issues in Basel III in relation to a countercyclical capital buffer. When BE/ME increases (decreases) during economic downturns (upturns), asset correlations are lower (higher), which in turn leads to a lower (higher) capital requirement. This regulatory mechanism induced by BE/ME can be used to attenuate the cyclical impact of the business cycle as lending activities tend to increase (decrease) due to a lower (higher) capital requirement during bad (good) times.

Our findings may also provide more broadly for a further understanding of BE/ME effect in the asset pricing literature. Our results on the BE/ME and its underlying sources of assets-in-place and growth options are consistent with the investment-based argument. In particular, firms with a varying investment policy (i.e., fixed versus variable assets) may experience different levels of operating leverage and therefore expected stock returns.

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