“The Impact of Bank Capital Requirements on Bank Risk: An Econometric Puzzle and A Proposed Solution”

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The impact of bank capital requirements on bank risk: an econometric puzzle and a proposed solution

Abstract

The relationship between bank risk and bank capital has been frequently discussed in the literature on banking. There is, however, an enigma remaining. Empirical studies have been inconsistent in their measurement of the impact of increased capital requirements on bank risk. Do higher mandatory capital requirements reduce risk in banking or do they actually increase bank risk? The problem stems from the basic endogenous relationship between risk and capital. In order to regress risk on capital we need an instrument for capital, but it is difficult to find an instrument that is related to a bank's capital that is not also related to the bank's risk. In this paper, we propose a solution. Using stochastic frontier analysis we develop an exogenous instrument for capital that is closely correlated with capital but not correlated with risk. We argue that this instrument will be a useful contribution to the analysis of this important topic.

Keywords: bank capital adequacy, risk management, capital requirements.
JEL Classification: G21, G28, G32.

Introduction

Rarely has the importance of bank capital requirements received more attention than in the past 18 months or so. The sub-prime mortgage debacle produced billions of dollars of losses that significantly reduced the capital of many large banks. Bank efforts to replace their lost capital continue today.

Bank capital adequacy, however, is not a new topic. Banks have always received special attention due to their ability to create money and due to the impact that bank information production and liquidity services have on the real economy. The primary purpose of bank regulation is to limit the negative externalities arising from bank failures and the primary tool of choice by regulators is minimum capital requirements.

Complicating the problem of bank solvency is the perverse nature of the federal bank safety net, especially deposit insurance. Since depositors are not worried about bank risk due to a government guarantee, banks are exempt from the normal discipline creditors exercise over their debtors. More importantly, in the face of non-risk based insurance premiums banks are directly motivated to maximize shareholder value by increasing risk. This is a classic moral hazard problem. Again, the traditional tool employed by bank regulators to deal with this problem has been the establishment of capital adequacy requirements. Arguments have been made, however, that mandatory capital requirements actually increase bank risk. In other words, as capital requirements are increased, banks increase their risk in order to earn the same return on capital.

Empirical studies, however, of bank capital and bank risk face an inherent problem. In order to measure the effect of the level of capital on bank risk-taking it would be useful to regress risk, as the dependent variable, on capital as the independent variable. However, there is an obvious endogeneity problem. The amount of risk you can undertake is dependent on the amount of capital you have and the amount of capital you need is dependent on the amount of risk you want to undertake. In other words, they are jointly determined, much like price and quantity in a basic microeconomic analysis.

The solution to this problem is normally to use either a simultaneous equation model or to use instrumental variables. However, a simultaneous equation model must be properly identified and no one has yet been able to accomplish that in regard to risk and bank capital. Likewise no one, to our knowledge, has yet found a true instrument for capital that is independent of risk. We present a methodology for the development of an exogenous instrument for capital in a regression with risk.

We propose to use stochastic frontier analysis to determine the maximum possible income that can be achieved from a given level of assets. This is referred to as fitting an upper envelope. Such a frontier is obviously exogenous to any specific bank because it is determined by the data from all banks in the sample. The distance from the frontier to any specific bank actual income can be considered a measure of bank inefficiency. In other words, this is a measure of how close the bank comes to maximizing its income based solely on the amount of assets employed.

In order to develop an instrument for capital we propose to create a second frontier conditioned on bank capital as well as the amount of assets employed. The incremental inefficiency from the second frontier is a function of the bank's capital but independent of the bank's risk, and it is this incremental inefficiency that we propose to use as an instrument for capital.

1. Capital regulation

Briefly let us review the current state of capital regulation. In 1988 the Basle Committee issued a capital measurement system usually referred to as the Basle Capital Accord or Basle Accord I. This was in response to the deteriorating capital position of many international banks at a time of perceived increase in risk. A key element of the Accord was a system of risk weightings based on the type of assets held by a bank. In other words, two banks of the same size would need different amounts of capital based on the different levels of risk in their assets. In addition, there was a uniform definition of what constituted "capital"; e.g. subordinated debt, loan loss reserves, etc. Finally, off-balance-sheet items were included in the calculation of required capital as well as on-balance-sheet items. After making these calculations, a bank was required to have capital equal to 8% of the risk weighted assets. The Accord appears to have been effective because by 1993 bank capital ratios had increased to 8.01% from 6.21% in 1988.

Modifications were made to the Basle Capital Accord during the 1990s. A significant change incorporated the problem of "market risk", in addition to "credit risk", into the analysis of capital adequacy. Currently a new Capital Accord is scheduled for a phase starting in 2008 and is generally referred to as Basle II. It represents an effort to fix some of the problems associated with the original accord. One major issue has been the potential for capital arbitrage between the original risk categories of Basle I. It is generally agreed that the original risk categories were too broad. Assets with significantly different risk parameters nevertheless required the same amount of capital to support them. For example, all commercial and industrial loans required the same amount of capital.

2. Literature review

As far back as 1977, writers have pointed out the incentives banks have to increase risk. Merton's 1977 article derives a formula to calculate the "fair" premium for deposit guarantees by the FDIC using what are now familiar option pricing techniques. He finds that the value of the premium is identical to a put option where the value of the bank debt is the strike price and the maturity is the next FDIC examination date. We know increasing risk will increase the value of options but because deposit insurance premiums were not based on risk, banks could, in effect, transfer wealth from the FDIC to shareholders by increasing bank risk. Merton's formula also allows us to measure the level of risk in a bank and the direction of any risk change by calculating the value of the deposit insurance. If the value of the insurance goes up the bank has become more risky. If the value of the insurance goes down, the bank has become less risky. In 1984 Marcus and Shaked took Merton's theoretical formula and made it operational for actual bank data. However, their findings at the time indicated that if anything, the then current deposit insurance premium was too high, not too low.

In another study, Keeley (1990) raised the question as to why it was not until the 1980s that banks started exploiting the federal safety net. His conclusion is that a bank's charter value, when it is high, serves to mitigate risk. In other words, banks limit the amount of risk they undertake in order to preserve their charter value. Keeley then documents the change in bank charter value from a premium over book value to a discount under book value. It was this decline in charter value during the 1980s that precipitated the exploitation of deposit insurance.

In a 1995 article, Berger, Herring and Szego review bank capital ratios from 1840 to 1990. In 1840 bank capital funded approximately one-half of bank assets. In 1863, the first National Banking Act created National Banks and the office of the Controller of the Currency to supervise these banks. This was perceived as reducing the inherent risk in the new national banks and so capital ratios did not need to be as high as they had been. In 1913-1914 the creation of the Federal Reserve System that included the "lender of last resort" function further reduced risk and banking and capital ratios declined again. In 1933 the FDIC was created and Regulation Q was promulgated to limit the interest rate a bank could pay on its deposits. Capital rates declined again. By 1989 the equity-to-asset ratio of banks was generally only a little over 6%.

It should be noted that in this article the authors point out that excessively high capital requirements can produce social costs through lower levels of intermediation. In addition, there can be unintended consequences such as risk arbitrage (increasing risk to offset the increase in capital and maintain the same return on capital), increased securitization, off-balance-sheet guarantees, etc., all of which could mitigate the benefits of increased capital standards.

It also needs to be noted that not everyone is in agreement with the use of capital requirements to mitigate risk in banking. Berger et al., as discussed above, included comments on potentially bad unintended consequences. In addition, Kim and Santomero (1988) argue that a simple capital ratio cannot be effective and any ratio would need to have exactly correct risk weights in a risk based system. Rochet (1992) agrees. John, Saunders, and Senbet (2000) argue that a regulatory emphasis on capital ratios may not be effective in controlling risk. Since all banks will have a different investment opportunity set, an efficient allocation of funds must incorporate different risk taking for different investment schedules. These authors go on to argue that senior bank management compensation contracts may be a more promising avenue to control risk using incentive compatible contracts to achieve the optimal level of risk.

There are also other alternatives to mandatory capital requirements that could be used to limit risk in banking. Prescott (1997) reviews the pre-commitment approach to risk management. Briefly, banks commit to a level of capital and if that level proves to be insufficient the bank is fined. This is used currently in the area of capital in support of a trading portfolio but cannot be used for overall capital ratios since a fine against a failed bank is not effective.

Gorton and Pennacchi (1992) discuss "narrow banking". This proposes splitting the deposit services of banks from the credit services. In other words, the financial system would include money market accounts and finance companies. The money market accounts would only invest in short-term high quality assets and leave the lending to the finance companies that would not take in any deposits.

Esty (1998) studies the impact of contingent liability of stockholders on risk. In the late 19th and early 20th century bank stockholders were subject to a call or an assessment for more money if needed to meet the claims on a bank. There was a negative relation between increases in risk and the possible call on bank stockholders.

Calomiris (1999) makes a strong case for requiring the use of subordinated debt in bank capital structures. The need to issue un-guaranteed debt and the associated market discipline would act as an effective limit to the amount of risk a bank would be able to assume.

3. Empirical studies

Empirical studies have been inconclusive in determining the impact of capital regulation on risk in banking. Duan, Moreau and Sealey (1992) address the question of risk-shifting to the FDIC directly. Merton's 1977 article established that the partial derivatives from the option pricing equation with respect to both variance and leverage are positive. The authors test this with real data and find that risk-shifting behavior is very limited.

However, Hovakimian and Kane (2000) use the identical empirical design and obtain opposite results. Interestingly, they also find evidence of a dichotomous strategy by banks. Highly levered banks tend to have high risk-shifting incentives while low leverage banks have low risk-shifting incentives. This supports Marcus (1984) who first argued that banks are forced to choose between a high-risk strategy and a low-risk strategy because a midrange policy is sub-optimal. Hughes, Lang, Moon, and Pagano (2003) also provide evidence of this. In a measure of bank efficiency, they document that high-leverage banks improve their efficiency by increasing their leverage further while low-leverage banks improve their efficiency by decreasing their leverage.

Empirical studies that are directly on point include Ambrose, LaCour-Little and Sanders (2003), Van Roy (2003), and Alexander and Baptista (2006). In a study of securitization, Ambrose et al. present evidence that lenders retain higher risk loans in their portfolio and sell lower risk loans in the secondary market. This practice represents regulatory capital arbitrage. On the other hand, Van Roy (2003) argues that his evidence documents that the 1988 Basel Accord did not result in banks taking on higher levels of risk. Finally, Alexander and Baptista (2006) argue that a VaR constraint imposed on bank trading portfolios can produce a perverse effect, namely that some banks may end up choosing riskier portfolios. It is apparent that this topic continues to generate interest. It is our argument that the proposed methodology will be a contribution to the literature in this field.

4. Data and methodology

We use a panel of data for bank holding companies for our analysis. The period covered is from 1993, the year after Basel I was fully implemented, to 2007. The number of banks in the sample ranges from 1,618 banks in 1993 to 964 banks in 2007. The total of bank-year observations is in excess of 25,000. The balance sheet data required are taken from the Federal Reserve Bank Form 9-Y. Table 1 (see Appendix) displays summary statistics on the data. To be effective, an instrument used in econometric analysis needs to be highly correlated with the independent variable in question, in this case capital, but not correlated with the dependent variable being studied, in this case risk. We proceed as follows.

Estimating production functions is standard fare in econometrics and a frontier production function simply represents the maximum output possible for a given level of inputs. To estimate the frontier we must be consistent with the proposition that all observations fall below the frontier. This requires us to use a regression that is fit to the data such that all observations do indeed fall below it. Formally, we use stochastic frontier analysis to develop a frontier, or upper envelope, of the pre-tax income earned based on the book-value of bank assets.

The estimate of a frontier is usually only a first step in calculating the efficiency of a cross-section of firms. The question we are asking is: "How efficient is a bank in converting the assets with which it has to work into pre-tax income? We argue that the frontier so developed is exogenous to any specific bank since it is based on the results of all banks in the sample. From the frontier we measure the inefficiency of each bank as the distance between the frontier and that specific bank's pre-tax income. This measure, however, must be adjusted for those elements that are beyond the control of the bank, i.e. the elements of luck.

The specifications of our unrestricted model are as follows:

$$PTI = \alpha + \beta_1 BVA + \beta_2 (BVA)^2 + \varepsilon$$
$$\varepsilon = v - u \qquad ,$$
$$v \sim iid\ N(0, \sigma_v^2) \qquad u(\geq 0) \sim iid\ N(0, \sigma_u^2)$$

Where PTI = Pre-tax Income; BVA = Book Value of Assets; v = statistical noise (luck); u = systematic shortfall (under management control).

Please note that a quadratic specification is used to allow for a non-linear relation between the pre-tax income and the book value of assets.

The frontier value is the deterministic kernel of the stochastic frontier:

$$FPTI_i = \alpha + \beta(BVA_i) + \gamma(BVA_i)^2 \ .$$

The stochastic frontier value is the deterministic kernel plus the two-sided error:

$$SFPTI_i = FPTI_i + v_i \ .$$

Therefore, we can see that:

$$u = SFPTI - PTI = FPTI - (PTI - v)$$
$$and \qquad .$$
$$E(u \mid \varepsilon) = FPTI - (PTI - E(v \mid \varepsilon))$$

Since the conditional expectation cannot be observed we must estimate it. The details of fitting stochastic frontiers can be found in Jondrow, Lovell, Materov, and Schmidt (1982) and Greene (1997).

This unrestricted frontier model determines the highest potential pre-tax income based solely on the book-value of assets employed. Now we want to narrow the definition and base the frontier value on the level of capital as well as the amount of assets. The implication of using the unrestricted model is that we are measuring the unconditional inefficiency of the banking organization. By conditioning the model on capital we can develop a measure of the incremental inefficiency of an organization due to its capital level. It is this incremental inefficiency due to a bank's capital level that we propose to use as the instrument for capital in a regression of risk on capital.

Our restricted model is specified as follows:

$$PTI = \alpha + \beta_1 BVA + \beta_2 (BVA)^2 + \beta_3 BVC + \varepsilon \ ,$$

where: PTI = Pre-tax Income; BVA = Book Value of Assets; BVC = Book Value of Capital; Epsilon = as specified in the base model.

Again, note that a quadratic specification is used to allow for a non-linear relation between pre-tax income and the book value of assets.

We save the estimate of u, the inefficiency level of each bank, from both the unrestricted model and the restricted model. We then calculate the incremental level of inefficiency by subtracting the restricted model results from the unrestricted model results. This change in inefficiency is due to the level of bank capital and is our instrument.

5. Results

We estimate our unrestricted model. The results are shown in Table 2 (see Appendix). As noted in our discussion of the basic stochastic frontier model, the composite error term, epsilon = "$v - u$", is asymmetric and non-normal. The term "v" is a two-sided error term representing the variance from the frontier value due to factors over which the bank has no control. Consistent with accepted practice we assume a normal distribution for "v". The term "u" is one-sided and represents the short-fall in frontier value due to factors over which the bank does have control. This is our measure of inefficiency and, again consistent with common practice, we assume a half-normal distribution for "u".

It is apparent that the asymmetry of epsilon is due to "u". The parameter, Lambda, is a measure of the asymmetry and is calculated by dividing sigma "u" by sigma "v". When Lambda equals zero, epsilon = "v" and is normally distributed. While there is no generally recognized level of Lambda that can be referenced, the statistical significance of Lambda provides support for a stochastic frontier specification.

The results presented in Table 2 show highly significant parameters for both total asset variables. In addition, we find a highly significant Lambda.

We estimate a restricted model using the same data. Our results are shown in Table 3. The results again show highly significant parameters for both total asset variables. The coefficient on capital is positive, a somewhat surprising result, and highly significant. We again find a highly significant Lambda.

In order to complete the development of our instrument for capital we save the estimated inefficiencies from both models. We then take the difference between the two estimated inefficiencies and employ it as our instrument.

To validate the instrument we regress our total capital variable on our instrument and the other explanatory variable, total assets. We find a highly significant coefficient on our instrument. We also note an increase in the F-value when we include the instrument in the regression compared with the same regression without the instrument. The results are shown in Table 4.

Conclusion and further research

The importance of the relationship between bank risk and bank capital has been well documented in the literature. In this paper we have developed an instrument for capital to be ultimately used in a regression of risk on capital. Such an instrument would be a solution to the obvious endogeneity problem associated with risk and capital.

We use stochastic frontier analysis to create an upper envelope of the pre-tax income generated from the book-value of that bank's assets and measure the level of inefficiency for each bank in our sample. We then create a second frontier conditioned on each bank's capital level as well as the book-value of their assets and again measure the level of inefficiency of each bank. The difference between these levels of inefficiency is our instrument. We argue that the incremental inefficiency is exogenous to the risk of any specific bank but correlated to that specific bank's capital. We validate the instrument by measuring the significance of the instrument in a regression of the instrument on the endogenous variable and the other explanatory variables.

There are numerous further research topics that can be pursued in line with this analysis. The first, and most obvious, is to employ the instruments in a regression of risk on capital. Another approach would be to limit the sample to publicly owned bank holding companies and use the market-value of assets as the dependent variable in lieu of pre-tax income. This would produce a frontier based on the maximum market-value of assets that can be attained with a given level of book-value assets. Finally, if the stochastic frontier analysis can be confidently used to develop instrumental variables the application of the process is extremely widespread.

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Appendix

Table 1. Summary statistics

Following is the summary of statistics of key variables included in the analysis. There are 25,066 observations for each variable. Amounts are in millions of dollars.

Variable	Minimum	Maximum		
Total assets	7,850	2,187,631,000	5,650,096	50,088,304
Total equity	-654,166	146,803,412	464,263	3,987,425
Pre-tax income	-7,192,723	32,007,503	93,773	869,234
Unrestricted inefficiency	87,871	3,221,789	997,633	119,860
Restricted inefficiency	61,108	2,240,535	702,189	95,985
Instrument for capital	-1,631,823	2,832,134	295,444	82,580

Table 2. Unrestricted frontier analysis

The dependent variable is Pre-tax income.

$$PTI = \alpha + \beta_1 BVA + \beta_2 (BVA)^2 + \varepsilon \quad \varepsilon = v - u \quad v \sim iid\ N(0, \sigma_v^2) \quad u(\geq 0) \sim iid\ N(0, \sigma_u^2),$$

where PTI = Pre-tax Income; BVA = Book Value of Assets; v = statistical noise (luck); u = systematic shortfall (under management control). The model is estimated using stochastic frontier analysis with maximum likelihood estimates. The error term equals v minus u. There are 25,066 observations. Values in parentheses are t-values.

Primary variables	Coefficient
Intercept	1,225,910
	(111.19)
Total assets	0.01988
	(250.69)
Total assets squared	-24,316,000,000
	(-68.46)
Parameters for compound error Lambda	1.8014
	(47.54)
Sigma	0.1287
	(269.5)

Table 3. Restricted frontier analysis

The dependent variable is Pre-tax Income.

$$PTI = \alpha + \beta_1 BVA + \beta_2 (BVA)^2 + \beta_3 BVC + \varepsilon \quad \varepsilon = v - u \quad v \sim iid\ N(0, \sigma_v^2) \quad u(\geq 0) \sim iid\ N(0, \sigma_u^2),$$

where PTI = Pre-tax Income; BVA = Book Value of Assets; BVC = Book Value of Capital; v = statistical noise (luck); u = systematic shortfall (under management control). The model is estimated using stochastic frontier analysis with maximum likelihood estimates. The error term equals v minus u. There are 25,066 observations. Values in parentheses are t-values.

Primary variables	Coefficient
Intercept	850,976
	(113.20)
Total assets	-0.0002288
	(-1.808)
Total assets squared	-14,310,300,000
	(-44.125)

Table 3 (cont.). Restricted frontier analysis

Total capital	0.239605
	(257.058
Parameters for compound error Lambda	1.8477
	(59.143)
Sigma	907,201
	(315.671)

Table 4. Validation of instrument

Dependent variable is Total Capital. Model 1 is the regression of Total Capital on Total Assets. Model 2 is the regression of Total Capital on Total Assets and the Instrumental Variable calculated. Values in parentheses are t-values.

Variable	Model 1	Model 2
Intercept	27,466	2,455,916
	(4.54)	(156.09)
Total assets	0.07731	0.07879
	(644.22)	(928.8)
Instrumental variable		-8.24797
		(-160.31)
F-value	415,022	433,111