Bank Competition and Loan Market Risk Taking: A Switching Cost Model with Risk Aversion

by

Dylan Brown

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Abstract

This paper is divided in to two sections. First, a critical review of the bank risk taking-market concentration literature will be carried out. In this section, much of the attention will be paid to discussing Boyd and De Nicoló's seminal 2005 paper that argues risk taking increases with concentration. Secondly, in response to criticisms made in the first section, a simple theoretical model of bank risk taking and market competition will be developed. This paper finds that using switching costs as a proxy for competition along with a limit pricing regime, banks will be incentivized to take on more loan market risk as competition increases. Furthermore, this incentive structure is exacerbated by the introduction of risk aversion and a loan market interest rate that is endogenous to success probability.

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The 2008 financial crisis reinvigorated academic interest in aggregate bank risk taking and its determinants. Myriad papers offer different, and often competing, views on the market conditions that elicit excessive risk taking by banks. The motivations for such research are obvious: the stability of the banking sector is of paramount importance to ensure access to credit and by proxy, economic growth. Accordingly, banking crises have an uncanny ability to cause contagion and spread into other areas of the economy. Secondly, as Boyd and De Nicoló note (2005), the theoretical economic literature on bank stability appears to have had, "a material impact on bank regulators and central bankers".

From the industrial organization perspective, one of the most salient research avenues in this field is the relationship between market concentration and bank risk taking. This paper will review, assess and improve upon the existing theoretical literature on this relationship. Outside the scope of the current literature, which is often micro-financial by nature, attention will be paid to the broader industrial organization/bank strategy connotations of concentration/competition in modelling.

1-A Simple Model of Banking Competition

It will be useful to frame the conceptual model of a banking market that will be referred to throughout the paper. This will serve as a foundation for subsequent discussion as it both clarifies some aspects of bank competition and raises important questions. Drawing from Van Hoose (2010), it is assumed that a bank i's profit function takes the following form:

$$\pi_i = r_L(L)L_i + r_s S_i - r_D(D_i)D_i - r_N N_i - C_i(S_i, D_i, L_i, N_i)$$

where L_i, D_i, S_i, N_i denotes firm i's quantity of loans, deposits, government securities and non-deposit liabilities, respectively. Because this is a static model, all assets can be considered to mature in one period. Interest rates on assets are r_L , r_s, r_D and r_N (loans, securities, deposits and non-deposit liabilities, respectively). It should be noted that the interest rate on loans is a function of the total amount of loans in the market, $L=L_i + L_{-i}$,where L_{-i} is the sum of all loans made by banks other than bank 'i'. Likewise, the interest rate on deposits is determined by the total amount of deposits in the market $D=D_i + D_{-i}$. For the purposes of parameterization, Van Hoose posits a generalized inverse market demand for loans to be $r_L=\delta r_s^{-\lambda}L^{1/\varepsilon}$ and an inverse market supply for deposits to be $r_D=\delta r_s^{-\alpha}D^{1/\eta}$ where δ, α, λ, ε and η are all greater than zero. Finally, a generalized cost function $C_i(.)$ is included and assumed to be identical for all firms. This assumption of Van Hoose will be relaxed later.

Taking this setup into consideration, bank i solves the following problem:

$$\max_{S_i, D_i, L_i, N_i} \quad r_L(L)L_i + r_sS_i - r_D(D_i)D_i - r_NN_i - C_i(S_i, D_i, L_i, N_i) + \lambda_i(L_i + S_i - (1\text{-}q)D_i + N_i)$$

where, the constraint in the Lagrangian reflects the fact that $R_i=qD_i$ and q is the required reserve ratio of the bank.

Solving the above problem yields the following F.O.Cs:

L_i: $\quad \delta r_S^{-\lambda}L^{1-\varepsilon/-\varepsilon}(L_i) + \delta r_S^{-\lambda}L^{1/\varepsilon} = -\lambda_i$

which can be factored to yield $(1\text{-}(L_i/L)\,\varepsilon^{-1})r^i_L - C^i_L = -\lambda_i$

D_i: $\quad (1+(D_i/D)\eta^{-1})r^i_D + C^i_D = (1\text{-}q)(-\lambda_i)$

S_i: $\quad r_S + C^i_S = \lambda_i$

N_i: $\quad r_N + C^i_N = -\lambda_i$

Assuming again that marginal costs are constant and homogenous among firms, we can impose $D_i = D_j$ and $L_i=L_j$ for $i\neq j$ and solve for the symmetric Cournot equilibrium quantities that will prevail in the market:

using the fact that $r_N + C^i_N=(1-(L_i/L)\,\varepsilon^{-1})r^i_L - C^i_L$ and imposing symmetry ($L=mL_i=mL_j$, where 'm' is the number of competitors in the loan market) the following obtains:

$$r_L=(m/m-\varepsilon^{-1})[r_N - C_N - C_L] \tag{1.1}$$

Combining the other two first order conditions and imposing symmetry once again we obtain,

$$r_D=(n/n+\eta^{-1})[(1-q)(r_S - C_S)-C_D] \tag{1.2}$$

where 'n' is the number of competitors in the deposit market.

Departing from the assumption that elasticities of demand are non-negative; result 1.1 suggests that loan interest rates will monotonically rise as the number of loan market competitors decrease. Likewise, result 2 suggests that the deposit rate offered to consumers will monotonically decrease as the number of deposit market competitors decrease.

The reason these results have been presented so early on in this paper are threefold. Firstly, it will be shown that it is problematic to assume a prototypical Cournot marketplace in the banking industry (something the extant literature on market concentration and bank risk taking is almost ubiquitously guilty of). These criticisms will be raised primarily in response to the dominant research on bank risk taking and market concentration. Secondly, the Cournot results above have implications on welfare in terms of consumer/producer surplus losses in response to concentration. Namely, the extant literature often ignores the impact of interest rates on general welfare by focussing too much on the risk aspects of welfare. These concerns are often ignored in literature, especially when it comes to policy prescriptions. Finally, because of the ubiquitous nature of the Cournot result(s), it is presented so that a clear framework can be used to discuss industrial organization issues with respect to bank risk taking. It will be shown that the implications of the Cournot model expressed above stretch far beyond the deposit and interest rate concerns raised in results 1.1 and 1.2.

2-Background

Before a more rigorous discussion can proceed, it will be useful to briefly discuss the historical thinking on bank risk taking and market concentration. Traditional notions in banking considered intense competition as something that would lead to greater risk of failures and panics. As Xavier Vives notes, most industrialized countries practiced heavily interventionalist banking sector policy from the 1940’s to the 1970’s (Vives, 2010). Authorities were content to control lending rates, investments, business diversification (i.e. forays into insurance and investment banking) and market concentration. Unlike traditional regulatory intervention in markets, however, authorities leaned toward keeping banking markets highly concentrated. Regardless of the liberalization of bank market intervention most scholars claim to have occurred since the 1970’s (in particular: Vives, 2010), bank markets in most industrialized countries remain concentrated enough to raise significant regulatory concerns (VanHoose, 2010).

The justification for highly concentrated banking markets is, at least at first glance, remarkably simple: following from the Cournot reasoning outlined in section 1, concentrated banking markets (presumably both on the deposit and loan sides) allow banks to charge high interest rates on loans while keeping costs low through low deposit rates. The resulting ability of banks to attain oligopolistic rents causes the banks to have a vested interest in maintaining the rents. Accordingly, they can be expected to minimize the risk of bankruptcy in order to maintain their valuable charter. In markets that are closer to perfectly competitive, conversely, banks have little incentive to minimize risk. Government backed deposit insurance is thought by many to exacerbate this problem with competitive banking sectors. Bank's incentive further favour risk taking activities due to the fact that large gains from risky activities stand to go to shareholders while large losses go to the government (Boyd and De Nicoló, 2005). This theory of market concentration and risk taking is often referred to as the "Charter Value Hypothesis"(henceforth CVH) promulgated by Allen and Gale(2001).

In contradiction to the CVH are theories arguing that lower bank market concentration will lead to less risk taking among banks in aggregate. Chief among these, is a paper by Boyd and De Nicoló (2005) that seems to have become the talking point of the market concentration and bank risk taking debate since its publication. At the very least, it seems to be one of the first challenges to CVH with theoretical traction. In light of this fact, this paper now turns its attention to briefly describing and then critiquing the Boyd and De Nicoló model (henceforth BDN).

3-BDN Cournot Model

An obvious problem with the simple Cournot model presented in section one is that direct mathematical representation of enterprise risk is not present in the model. It has been the challenge of modellers to incorporate risk into it, while still maintaining Cournot-Nash competition in banking markets. For the question at hand, i.e. the relationship of market concentration to risk taking, it is important to allow some risk parameter to vary with some proxy for the level of concentration in the economy.

Allen and Gale (2000) used a portfolio problem focusing on deposit market competition and risk choice by banks to show that the charter value hypothesis holds under general assumptions and Cournot competition. The BDN model uses the same notation but extends the model to allow for loan market competition in addition to deposit market competition for reasons that will be made clear shortly. The model is setup as follows:

Entrepreneurs have access to a set of constant returns to scale risky technologies indexed by the parameter s. The entrepreneur's payoff matrix takes the following form:

$$return = \begin{cases} s \text{ with probability } p(s) \\ 0 \text{ with probability } 1 - p(s) \end{cases}$$

so that returns are binary and idiosyncratic project risk is ruled out (i.e. default probabilities are perfectly correlated among entrepreneurs). Furthermore, it should be noted that p(S) must satisfy $p(0) = 1$, $p(S^U) = 0$, $p'(S) < 0$ and $p(S)'' \leq 0 \ \forall \ S \in [0, S^U]$ for a unique solution to be obtained.

An inverse supply of total deposits is defined identically to the initial Cournot model presented in section 1 so that r_D=$r_D(D)$ where $D=\sum_{i=1}^{N} D_i$. For uniqueness, it is specified that $r_D(0) \geq 0$, $r_D'(D) > 0$ and $r_D''(D) > 0$. In order to account for aforementioned effect of deposit insurance on bank decision making, BDN introduces a constant factor cost for government deposit insurance 'α' so that αD_i, the amount paid for deposit insurance, is linearly increasing in the size of firm i's deposits.

On the loan side of the market, there is no deviation in notation from the Cournot model of section 1. The inverse demand for loans takes on the functional form r_L=$r_L(L)$ where $L=\sum_{i=1}^{N} L_i$. Note that in this case, the loan market number of competitors is specified to be equal to the deposit market number of competitors: N. Furthermore, uniqueness requires that the following conditions are imposed upon the demand: $r_L(L) > 0$, $r_L'(L) < 0$ and $r_L''(L) \leq 0$. A second departure from the Cournot model presented in section one is that firms are not allowed to hold equity or non-deposit liabilities. Accordingly, L=$\sum_{i=1}^{N} D_i$ so that r_L=$r_L(\sum_{i=1}^{N} D_i)$.

In the Cournot solution for deposit market interest rates stated in equation 2, the interest rate on equity (government bonds) 'r_s' has a direct effect on deposit rates. Boyd and De Nicoló revisit their model (2006) with an allowance of firms to purchase equity. The results are much more mathematically cumbersome, but largely the same as their seminal 2005 paper.

This being said, the following is a presentation of the more simplistic 2005 BDN result. Following from the notation above, entrepreneurs face the following problem:

$$\max_S \quad p(s)(s-r_L)$$

with solution,

$$s+\frac{p(s)}{p'(s)}=r_L \tag{3.1}$$

The entrepreneur's problem reflects the binary nature of payoffs and the fact that repayment of the loan need not occur if the project fails. The first order condition shows that entrepreneur choice of risk is increasing in the interest rate (which can be shown by differentiating the left side of 3, and using the conditions imposed on p(S)). This result, which becomes a constraint on bank i's profit maximizing problem, is a condition aimed to induce the credit rationing problem described by Stiglitz & Weiss (1981).

Accordingly, bank 'i' faces the following problem:

$$\max_{D_i} \quad p(s)(r_L(\textstyle\sum_{i=1}^{N} D_i)D_i - r_D(\sum_{i=1}^{N} D_i)D_i - \alpha D_i) \quad \text{s.t. } s+\frac{p(s)}{p'(s)}=r_L$$

which consolidates to,

$$\max_{D_i} \quad \pi(D_i)=p(S(\textstyle\sum_{i=1}^{N} D_i))[\, r_L(\sum_{i=1}^{N} D_i)D_i - r_D(\sum_{i=1}^{N} D_i)D_i - \alpha D_i] \tag{3.2}$$

Boyd and De Nicoló show that in a symmetric Nash (Cournot) equilibrium that, "The equilibrium level of risk shifting S is strictly decreasing in N"(2005, 1338). Their result implies the following: if banks in an imperfectly competitive market try to exercise market power and increase loan rates above the perfectly competitive level (as equation 1.1 in the simple Cournot model suggests they will), entrepreneurs will be incentivized to take on more risk and the probability of bank failure will increase monotonically with N. Importantly for BDN's rebuttal of CVH, Boyd and De Nicoló note that "The banks are aware that this response [increased risk taking by entrepreneurs] will occur and take it into account in their choice of a loan rate".

Since 2005, the onus seems to have been on the CVH /"competition fragility" proponents to discredit the "competition stability"(Beck, 2008) proponents (mainly BDN). Criticism has largely fallen into the category of robustness issues within the BDN model itself, namely Hakenes & Schnabel (2007), Martinez-Miera & Repullo(2010) and Wagner(2010). These will be discussed, but the main purpose of this paper, as stated earlier, is to focus on the industrial organization issues with BDN. Namely: how BDN neglects to take in to consideration some of the myriad exceptions to Counot reasoning. These industrial organization issues will largely be discussed with reference to the simple Cournot model derived in section 1. Secondly, some more general robustness issues of BDN will be discussed as a segue in to a more comprehensive model of bank risk taking and competition.

4-Industrial Organization and BDN

As mentioned earlier, the BDN result differs from the Allen and Gale charter value hypothesis result in that a "lending channel" (Boyd and De Nicoló, 2005) is introduced. More specifically, their result hinges on the assumption that banks existing in an imperfectly competitive world will try to exercise market power and raise interest rates. Given the setup of the BDN model, it is an optimal choice of banks to do so, even after taking in to account the risk shifting effect it will have on entrepreneurs. This section will aim to point out some of the assumptions and/or fallacious reasoning that are necessary for such a result to occur.

4.1: Governance

Before an exploration of the more traditional industrial organization issues can be undertaken, it will be useful to consider the role of bank governance in interest rate decisions. Charter value hypotheses and the broader "competition fragility hypothesis" view banks as entities that are beyond all else, profit maximizing. BDN also makes the assumption that banks are profit maximizing, but assumes they are willing to trade higher return variance for a higher expected value of profits. The problem with Cournot results, even in the risk adjusted Cournot model of BDN, is that profit volatility is almost never explicitly enters the bank's objective function. Take BDN's aforementioned assertion that "The banks are aware that this response [increased risk taking by entrepreneurs] will occur and take it into account in their choice of a loan rate". This statement is guised as a bank consideration of profit variability, but merely suggests that banks acknowledge their increased interest rates will induce greater risk, and ignore this risk for the profit incentives. If banks are made to be risk averse, as will be shown in section 6, the conclusions of BDN are called in to question.

4.2: Cost Issues

A second and more traditional "industrial organization" reason for banks not to exercise market power and raise interest rates are cost function changes as a result of concentration changes. The simple Cournot result presented in section 1, BDN and other theoretical models of the bank risk-taking ignore the possibility of such cost permutations.

In the interest of clarifying this point, consider equations (1.1) and (1.2) from section 1 for example

$$r_L = (m/m - \varepsilon^{-1})[r_N - C_N - C_L] \quad (1.1)$$

$$r_D = (n/n + \eta^{-1})[(1 - q)(r_S - C_s) - C_D] \quad (1.2)$$

Looking at the above solutions to the Cournot game, it is clear that the loan rate is a function of the interest rate on non-deposit liabilities, the marginal cost of obtaining non-deposit funds 'C_N' and the marginal cost of lending 'C_L'. These solutions call in to question the earlier assertion that the loan rate 'r_L' is strictly increasing in the number of loan market competitors 'm' if, in particular, the marginal cost of non-deposit funds/liabilities and lending change with 'm'. In the case of BDN, the cost implications are identical save the aforementioned point that BDN only considers deposit costs in their model. In the interest of robustness, therefore, the former model is focussed on.

The idea that cost structures are endogenous with concentration in imperfect competition was made popular by Demsetz (1973) and is often referred to as the "Efficient Structure" challenge to the concentration implications asserted in section 1. The implications it has for BDN are obvious; if marginal costs 'C_L' and 'C_N' are substantially reduced as a result of a mild decrease in 'm', loan rates might decrease or remain the same as a result of reduced competition[1] . Accordingly, entrepreneurs will have no incentive to take on more project risk and the "risk-shifting " effect that is the backbone of the BDN hypothesis is negated.

4.3: Limit Pricing/Strategic Entry Deterrence

Another pertinent reason banks might be reluctant to raise interest rates in response to

[1] A more strong proposition might suggest that for relevant domains of 'm', marginal costs are monotonically decreasing in 'm'.

market power is to deter entry of other banks in to the market. Following from equations 1.1 and 1.2, increases in the number of firms in the loan and deposit markets will cause Cournot equilibrium interest rates to decline and increase, respectively. The profit consequences from such entry have been outlined earlier. What is important to notice here is the similarity among the aforementioned charter value hypothesis and the premise of entry deterrence.

A rudimentary strategy of entry deterrence applied to banking suggests that banks might not have an incentive to raise interest rates and obtain larger profits (as BDN predicts) due to the fact that large rents might induce entry in to the banking market. Regardless of the level of market power a bank has, banks might price loans and deposits so that the post entry level of profits will be lower than the cost of entry in to the market and/or recurring fixed costs. In BDN, the equilibrium deposit and loan rates (r_L and r_D) are taken as completely exogenous to the number of banks in the market 'n'. There is reason to think that these rates, which are integral to the revenue and cost side of the bank profit function, will significantly affect profits (charter value) and by proxy, entry incentives. A careful model of banking market competition and risk taking should take account of this relationship and the fact that it might be profitable for a bank to try to deter entry through strategic rate setting.

4.4: Relationship Lending and Informational Rents

A final salient industrial organization issue that is overlooked in the bank risk taking-concentration literature (particularly BDN and Allen & Gale) is the issue of relationship lending and competition. Following the exposition of Boot and Thakor (2000):

> "[B]anks develop close relationships with borrowers over time. Such proximity between the bank and the borrower has been shown to facilitate monitoring and screening and can overcome problems of asymmetric information. In this view, relationships emerge as a prime source of an incumbent bank's comparative advantage over *de novo*

lenders"(1)

In the model to be presented in this paper, switching costs will be used to reflect relationship lending in banking. More specifically, the cost to an entrepreneur of switching banks will increase as market concentration increases. This setup reflects the assumption that when there are few banks (and switching is less of an option), there are informational advantages to the bank.

5- Robustness: Directions for an Adjusted Model of Bank Risk Taking and Competition

This section will aim to build on the propositions made in the last section but with particular attention to robustness issues in BDN that could significantly affect the paper's conclusions. This will be done both for the purpose of questioning BDN intrinsically, and establishing relevant directions for a more robust model of bank competition and risk taking.

As a preliminary note to this discussion, it should be briefly pointed out that the aforementioned elimination of equity from a bank's profit function will not be discussed as a robustness issue. As stated earlier, Boyd and De Nicoló established (2006) that introduction of equity into their benchmark BDN model had the effect of making the relationship between concentration and bank risk taking non-monotone. Nevertheless, the discontinuous relationship among the two parameters still favoured the "competition stability" view that increased competition leads to lower bank risk taking. Consequently, it will be assumed that the equity-adjusted BDN model will produce the same general results as the base BDN model, regardless of what permutations are imposed upon it.

<u>5.1: Approach to Risk</u>

In BDN (and Allen and Gale before them) entrepreneurs are indexed by risk choice 'S' which is bounded along the interval S ε [0, S^U]. Entrepreneurs choose their risk according to their risk-return objective function (3.1) [(S -r_L)p(S)], and banks face the entrepreneur's optimal choice as a constraint on their profit function. There are two reasons the model presented in section 6 does not use the same characterization of risk as this.

In the model presented in section 6, banks are allowed to influence the risk choice of entrepreneurs with an instrument other than the loan market interest rate. This adjustment is aimed to reflect the fact that banks can indirectly influence risk in through activities like screening, choosing which industry to lend to and adjusting the loan size.

5.2: The Margin Effect

In BDN, the loan market interest rate is a key device in determining entrepreneur risk choice, and in turn, the risk of failure. Martinez-Miera & Repullo (2010) point out, however, that lowering the loan market interest rate (as a result of competition) will make interest payments on performing loans lower and thus increase the aggregate probability of bank failure. The reverse is true in the case of loan market rate increases. This endogeneity among the probability of failure and the loan market rate is referred to by Martinez-Miera & Repullo as the "margin effect", and works in the opposite direction of the familiar "risk-shifting effect" of BDN. In order to account for it, however, imperfect correlation of default (idiosyncratic risk) is needed.

5.3: Concentration vs. Competition

Up until this point, market concentration has been used as a proxy and/or synonym for competition. The simple Cournot model in section 1, Allen and Gale, BDN and Martinez –Miera & Repullo (henceforth MMR) use the number of firms in the loan market 'n' as the latter rather than the former. This paper uses the aforementioned switching cost device as a proxy for competition instead of the number of firms for two reasons. First, concentration does not necessarily imply competition. Any amount of collusion/anti-competitive behaviour renders concentration moot as a proxy for competition. Secondly, if the market contains a dominant firm, the addition of inframarginal firms should not affect loan market rates whatsoever. This paper opts to use switching costs due to its directness and its ability to avoid these two problems.

6- MMR and a Model of Bank Competition and Risk Taking

6.1: MMR and the Wagner model

Up until this point in the paper, a long list of criticisms has been levied against the classic BDN result. As mentioned earlier, MMR (2010) addresses many of the robustness issues of BDN brought up in section 5 using BDN as an initial framework. Firstly, they change the model to allow for idiosyncratic risk (so that project failures can be imperfectly correlated). Secondly, they change the basic BDN model so that failures are continuously distributed in magnitude rather than binary. Third, and perhaps most importantly, they impose endogeneity among the interest rate charged by the bank and the probability of failure.[2]

This is done to reflect the fact that greater bank competition implies a lesser interest rate and reduces the interest payment on performing loans, so that risk might be increasing with competition in (at least) this avenue. MMR refer to this effect as the “margin effect”, and it is easy to see how it works in the opposite direction of the BDN “risk shifting effect” that was the brunt of their paper: in former case, interest rate decreases might increase risk due to the

[2] as discussed in section 5.2

lesser payback rate of performing loans, in the latter, interest rate increases might increase risk due to the incentives of entrepreneurs to take on riskier projects in response.

In the words of MMR:

> "[I]n general there is a U-shaped relationship between competition (measured by the number of banks) and the risk of bank failure. In other words, in very concentrated markets the risk-shifting effect dominates, so entry reduces the probability of bank failure, whereas in very competitive markets the margin effect dominates, so further entry increases the probability of failure"(2)

MMR proceed to show that this U-shaped relationship obtains even when the deviation from perfect correlation of failures (no idiosyncratic risk) is mild. This casts doubt on the plausibility that BDN is accurate in the long run once idiosyncratic risk is minimized. Secondly, the authors show that a repeated Cournot game among the same set of entrepreneurs will cause increased prudency among banks at all concentration levels due to the ability to retain franchise value.. Third, and finally, the authors show that the U-shaped relationship obtains for spatial Cournot competition for both static and dynamic games.

The results of the MMR paper are important for two reasons. Firstly, they address nearly all of the key robustness issues in BDN. Secondly, they non-linearize the traditional BDN relationship, making it true for a certain domain of the risk-concentration relationship. On the other hand, much of the industrial organization issues of BDN were completely ignored by MMR.

For this reason, the benchmark model to be used in this paper is an approach devised by Wolf Wagner (2010) that uses switching costs as a direct measure of competition, a simpler characterization of idiosyncratic risk than MMR, and a limit pricing rather than Cournot framework for bank interest rate pricing. These mechanisms will be discussed in more detail when framing the model. As an initial remark, however, it should be noted that Wagner elected to look at the effect of a competition parameter 'c' on marginal risk taking incentives for any given project risk level 's'. His result that the marginal profit incentives of risk taking are strictly increasing with competition will be used as a benchmark in 6.2.

6.2: Model of Bank Competition and Risk Taking

6.2.1: Setup

Assume, like BDN, that there are two dates (0 and 1) and that entrepreneurs, depositors and banks exist. Secondly, depositors can invest in a risk free asset that grants return r_f for every unit invested at time 0. Deposits are assumed to be fully insured at premium β so that a bank can raise funds at $r^D=r_f+\beta$.

Entrepreneurs are indexed by risk parameter k (with $k \varepsilon [k_{min}, k_{max}]$) where entrepreneur k's payoff is (s-k) if the project is successful. In the case of failure, the project pays zero. It can be seen here, that k is an indicator of an individual's riskiness since a higher k will induce them to take on a higher project risk s (as will be shown formally later). Secondly, it is clear that risk is idiosyncratic in the sense that true project risk s is not directly related to actual entrepreneur risk k. Finally, it can be seen that the bank can indirectly control the risk of a project through its observation of k, as was advised in section 5.1.

This paper departs from BDN and Wagner (henceforth WW) in its approach to the probability of success 'p'. It will be specified that p is a function of risk level 's' and loan interest rate 'r'. The success probability function's derivatives are assumed to exist and satisfy the following restrictions: $p(s,r) > 0$, $p_s < 0$, $p_r < 0$, $p_{ss} < 0$, $p_{rr} < 0$ and $p_{rs} = p_{sr} = 0$ $\forall$ $s \varepsilon [0,s_{max}]$, $r \varepsilon [0,1]$. This specification with respect to risk parameter 's' is identical to BDN and WW. The introduction of the interest rate in the failure probability function in conjunction with the specification that $p_r<0$ (where $p_r = \frac{\partial p}{\partial r}$) is to reflect the fact that higher interest rates make a project more difficult to pay off so that success probability with degenerate failures should be decreasing as the loan interest rate ‘r’ increases. This is aimed to reflect the specification that produced the aforementioned “margin effect” in MMR.

The model works as follows: at stage zero the bank observes and chooses one entrepreneur indexed by k and offers them a loan interest rate ‘r’. After observing the incumbent bank’s offer, the entrepreneur has the option to switch to another bank which makes the interest rate offer of r_e. If the entrepreneur switches to the other bank he must pay switching cost ‘c > 0’, where c is assumed to decrease as competition intensifies. Accordingly, c is an, “inverse measure of competition”(Wagner, 2010). This specification is aimed to reflect the fact that searching for a new bank is costly to the entrepreneur. Increased competition expands the entrepreneurs options and lowers their search cost. After deciding which bank to obtain a loan from, the entrepreneur chooses his risk level ‘s’.

6.2.2: Solution

The model is solved backward so that the individual’s risk choice is considered first. Given loan rate r and risk type k, an entrepreneur will choose s to maximize his expected payoff which is the following[3]:

$$(s\text{-}k\text{-}r)p(s,r) \tag{6.1}$$

where the first order condition w.r.t. ‘s’ is:

$$p(s,r) + (s\text{-}k\text{-}r)p_s=0 \tag{6.2}$$

[3] s and k are assumed to be normalized to the domain [0,1] so that they can be interpreted as rates

which becomes a binding constraint on the bank's interest rate setting behaviour. Rearranging to solve for s yields:

$$s = \frac{-p(s,r)}{p_s} + k + r$$

taking the implicit partial derivative w.r.t. 'r' yields:

$$\frac{\partial s}{\partial r} = p(s,r)p_{ss}^{-2}\frac{\partial s}{\partial r} - p_s p_s^{-1}\frac{\partial s}{\partial r} - p_r p_s^{-1} + 1$$

so that,

$$\frac{\partial s}{\partial r} = (p_r p_s^{-1} + 1)(-p(s,r)p_{ss}^{-1}) > 0$$

since, $p_{ss}^{-1}<0$.

The result that $\frac{\partial s}{\partial k} > 0$ can be obtained by the same procedure.

These results imply that the traditional risk shifting mechanism of BDN holds in this model: increases in the interest rate 'r' as well as the risk index 'k' increase the level of project risk taken on by the entrepreneur. Defining the optimal risk choice s(r), we know that the entrepreneur will not switch to the entrant if and only if the following inequality holds. This inequality reflects the assumption that an incumbent bank will use a limit pricing strategy to exclude entry.

$$(s(r) - k - r)p(s(r), r) \geq (s(r_e) - k - r_e)\, p(s(r_e), r_e) - c \tag{6.3}$$

In the second stage, interest rates are set. The lowest interest rate the entrant can charge without making a loss is r^D, whereby the entrepreneur's return net of any switching costs can be defined as:

$$U^D = (s^D - k - r^D)p(s^D, r^D) \tag{6.4}$$

so that assuming a binding constraint we get,

$$(s - k - r)p(s,r) = U^D - c \tag{6.5}$$

The introduced endogeneity of success probability and the loan rate has changed 6.3 and 6.4 from the WW benchmark. Notably, the only change in 6.3 is the different specification of the success probability function p. Since $p_{rr}<0$ in this particular specification (rather than $p_{rr}=0$ in WW), we know that the difference between the left hand side and the right hand side of 6.3 will be lower for any given 'r' and 'r_e' than the base case. This result implies that, the "tightness" of the constraint brought on by the imposed endogeneity among p and r should inhibit the ability of the incumbent firm to safely limit price. Secondly, because of the higher (relative) probability of success brought on by the fact that p(s,r) is non-linear in r and r^D, entrepreneurs going with the entrant can afford to take on more s-risk and attain higher relative expected profits to compensate. Accordingly, U^D is higher relative to the right hand side of 6.3 for all r where $r \neq r^D$ and $r^D<r$.

Since the incumbent bank's margin is the interest rate they charge less r^D, we can say that the expected profit function that the bank evaluates can be written as follows:

$$\pi = (r-r^D)p(s,r) - \alpha s \tag{6.6}$$

In 6.6, this paper again deviates from WW in introducing a risk aversion parameter for the bank 'α' that grows linearly with project risk 's'. Secondly, and following from the exposition in the preceding paragraph, the bank's margin $r-r^D$ must decline (relative to WW). This will be shown to affect the bank's unconditional (on competition) choice of risk.

Since we are interested in the relationship of marginal profit incentives of risk taking and competition, we first differentiate 6.6 with respect to 's' to yield the following:

$$\frac{\partial \pi}{\partial s} = r'(s)p(s,r) + (r - r^D)p_s - \alpha \quad (6.7)$$

Since $r'(s) > 0$, $p(s,r) > 0$, $(r - r^D) > 0$ and $p_s < 0$, there are two offsetting effects of increased risk taking on the part of the bank. On one hand, the higher interest rate the bank charges with increased risk will create more profits if the project is successful. On the other, the project is less likely to be successful since $p_s < 0$. There are two other effects the model addendums have caused. First, the bank's profit margin on successful loans $(r - r^D)$ decreases relative to the base case since inequality 6.3 has tightened. Accordingly, the bank will have a less powerful incentive to increase the risk level *ceteris-paribus*. Secondly, it can be seen that the effect of bank risk aversion is to simply decrease the marginal incentive for risk taking at all levels of profit. We now turn our attention to how these incentives change as the competition parameter 'c' is perturbed. To do this, consider the total differential of π'(s) with respect to 'c' while holding s constant at some level; $\bar{s}$:

$$\frac{\partial \pi'(\bar{s})}{\partial c} = \frac{\partial r'(\bar{s})}{\partial c} p(\bar{s}, r) + r'(\bar{s}) p_r \frac{dr}{dc} + \frac{\partial r(\bar{s})}{\partial c} p_s(\bar{s}) \quad (6.8)$$

Note in 6.8 that the risk aversion parameter 'α' disappears. This suggests that risk aversion does not affect the marginal profit incentives from risk taking as competition changes. This result obtains because risk aversion is specified to be exogenous to competition in this case, an assumption that is revised in section 6.2.3. Secondly, it should be noted that the WW model only had the first and third terms of 6.8. Since $\frac{\partial r'(\bar{s})}{\partial c} = 0$ and $(\frac{\partial r(\bar{s})}{\partial c} > 0)$[4], Wagner concludes that $\frac{\partial \pi'(\bar{s})}{\partial c} < 0$ so that the bank, following an increase in competition and an adjustment of k such that its previous risk level $\bar{s}$ is restored, its risk taking gains are still higher

[4] The proof of this is shown in the appendix

than they were before the change in 'c'(Wagner, 2010). Accordingly, the bank can implement a higher risk level 's'. To clarify; risk tends to increase with competition if banks can influence risk. This result is consistent with the charter value hypothesis of bank risk taking and completion. The question then, is how does the endogeneity among success probability and the interest rate affect the result of WW?

To assess this question, only the second term of 6.8 ($r'(\bar{s})p_r\frac{dr}{dc}$) needs to be evaluated. From the specification of functions, it is known that $r'(\bar{s}) < 0$ and $p_r < 0$ so that the sign of $\frac{dr}{dc}$ will be pivotal in the second term's affect on $\frac{\partial \pi'(\bar{s})}{\partial c}$. To sign this term we start from equation 6.5 and take partial derivatives of the implicit function:

$$(s - k - r)p(s,r) = U^D - c \qquad (6.5)$$

Rearranging to solve for r implicitly:

$$r = s - k - (U^D - c)p(s,r)^{-1}$$

Partially differentiating and solving:

$$\frac{\partial r}{\partial c} = p(\bar{s},r)^{-1} - cp_r\frac{\partial r}{\partial c}p(\bar{s},r)^{-2}$$

$$\frac{\partial r}{\partial c}(1 + cp_r p(\bar{s},r)^{-2}) = p(\bar{s},r)^{-1}$$

$$\frac{\partial r}{\partial c} = \frac{1}{p(\bar{s},r)(1 + cp(\bar{s},r)^{-2}p_r)} \qquad (6.9)$$

since $p(\bar{s},r) > 0 \;\forall\; s,r$ we know the following:

$$for\ any\ given\ \bar{s},r \begin{cases} \dfrac{\partial r}{\partial c} > 0\ iff\ p(\bar{s},r)^{-2} > |cp_r| \\ \dfrac{\partial r}{\partial c} = WW\ level\ iff\ p(\bar{s},r)^{-2} = |cp_r| \\ \dfrac{\partial r}{\partial c} < 0\ iff\ p(\bar{s},r)^{-2} < |cp_r| \end{cases} \tag{6.10}$$

Holding r and s constant, it is clear that $\frac{\partial r}{\partial c}$ is a function of c. The broader question to be asked, however, is how does the above relationship affect assertions regarding marginal risk taking incentives $\frac{\partial \pi'(\bar{s})}{\partial c}$ in 6.8? Working down the cases in 6.9: if $\frac{\partial r}{\partial c} > 0$, implying competition is relatively low, marginal risk taking incentives 6.8 will tend to be lower than WW predicts (depending on the magnitude of $\frac{\partial r}{\partial c}$). Secondly, if $\frac{\partial r}{\partial c} = 0$, implying that competition is relatively moderate, the marginal risk taking incentives will be identical to WW (and lesser than the previous case). Finally, if $\frac{\partial r}{\partial c} < 0$, implying competition is relatively high, the marginal risk taking incentives for any given s,r combination will be substantially higher than WW (and quite possibly positive). Another way to show the same relationship as 6.10 is to differentiate 6.9 to show that $\frac{\partial r}{\partial c}$ is strictly decreasing in c, which in turn implies that $\frac{\partial \pi'(\bar{s})}{\partial c}$ is increasing in 'c' (or decreasing in competition). Figure 1 depicts the relationship among marginal risk taking incentives and competition (the inversion of 'c') as predicted by this augmented WW model.

<u>Figure 1: Change in Marginal Profit with respect to Competition</u>

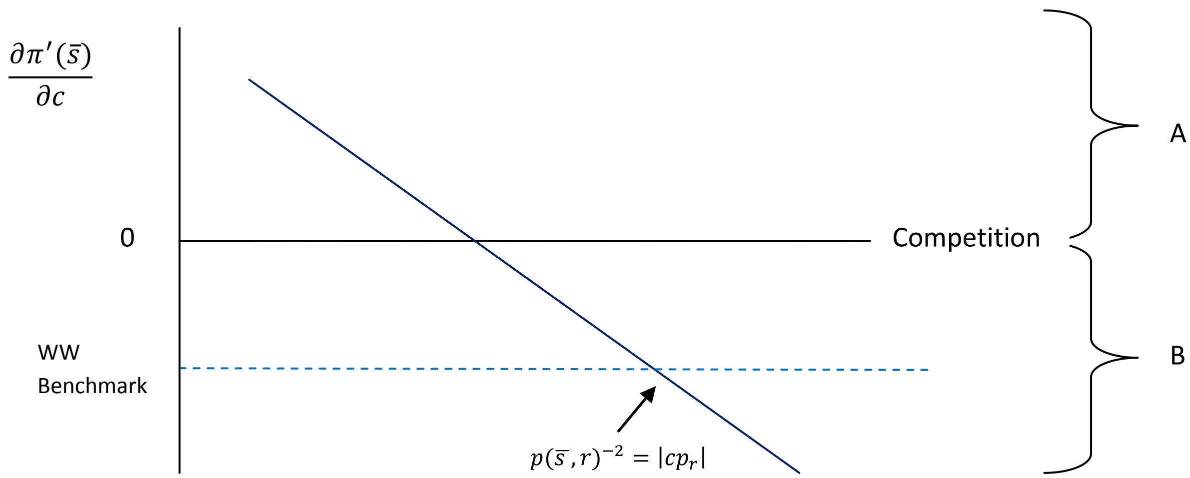


Figure 1 shows the WW benchmark of $\frac{\partial \pi'(\bar{s})}{\partial c}$ which is constant with respect to competition and negative. The slanted line depicted in the diagram is the function (6.8) which varies linearly with the level of competition. It is important to consider the metrics in the above diagram. In region B where $\frac{\partial \pi'(\bar{s})}{\partial c} < 0$, the scenario is identical to the one outlined by WW. Since $\frac{\partial \pi'(\bar{s})}{\partial c}$ is negative in this region, after a bank has adjusted k so that 's' returns to its pre-change level '$\bar{s}$', an increase in competition will incentivize the bank to increase risk. In region A, the exact opposite is the case and banks will be incentivized to take on less risk in response to a decrease in competition (to a decreasing degree).

6.2.3: Alternative Risk Aversion Specification

In this section it will be assumed that the bank's profit function depends on a variance parameter 'σ' and a parameter of risk aversion 'α>0' (which is identical to the preceding section). Accordingly, the bank's profit function takes the following form:

$$\pi = (r - r^D)p(s) - \alpha(r - r^D)\sigma(p(s))$$

which can be factored to: $\pi = (r - r^D)[p(s,r) - \alpha\sigma(p(s))]$ (6.11)

It will be specified that $\sigma(p) > 0$, $\sigma'(p) < 0$ and $\sigma(p)\ \varepsilon[0,1]$ so that increases in the probability of success lower the variance of the project 'σ'. Since increases in project risk 's' decrease the probability of success, increases in 's' also have the effect of increasing the variance parameter σ. From 6.11 then, it is clear that increased risk will have a negative effect on the objective profit function of the bank. This can be interpreted as the bank being 'punished' for increased risk taking.

Secondly, for profit to be positive, the restriction must be imposed that $\alpha\sigma(p) \leq p(s)$ for all values of 's'. Finally, it should be noted that the specification of 6.11 ignores the endogeneity of 'p' and 'r' that the previous section discussed. The reason for this is that the implications of this risk aversion specification are identical regardless of the specification of p.

Differentiating 6.11 with respect to 's' as in the previous case yields the following:

$$\frac{\partial\pi}{\partial s} = r'(s)p(s) + (r - r^D)p_s - \alpha r'(s)\sigma(p) - \alpha(r - r^D)\frac{d\sigma(p)}{dp}p_s$$

$$\frac{\partial\pi}{\partial s} = r'(s)[p(s) - \alpha\sigma(p)] + (r - r^D)p_s[1 - \frac{d\sigma(p)}{dp}] \qquad (6.12)$$

From 6.12, it is clear that risk aversion affects marginal bank risk taking incentives in a predictable manner relative to the WW benchmark. The first term, which is the marginal benefit of risk taking, is decreased by a factor of $p(s) - \alpha\sigma(p)$. Secondly, the bank's marginal cost of risk taking increases by a factor of $[1 - \frac{d\sigma(p)}{dp}]$. These two factors accrue to suggest that the bank will unambiguously take on less risk than in WW. Unlike the previous specification of risk aversion however, the marginal benefit of risk taking is reduced. Secondly, marginal benefit and marginal cost are non-linearly adjusted so that risk aversion will affect the competition-risk taking relationship. To see this, the total derivative of 6.12 is taken with respect to c around a constant s=$\bar{s}$ to yield the following:

$$\frac{\partial \pi'(\overline{s})}{\partial c} = \frac{\partial r'(\bar{s})}{\partial c} p(\bar{s}, r) + \frac{\partial r(\bar{s})}{\partial c} p_s(\bar{s}) - \alpha \frac{dr'(\bar{s})}{dc} \sigma(p)$$

$$- \alpha r'(\bar{s}) \frac{d\sigma}{dp} \frac{dp}{dc} - \alpha \frac{dr(\bar{s})}{dc} p_s(\bar{s}) \frac{d\sigma}{dp}$$

since $\frac{\partial r'(\bar{s})}{\partial c} = \frac{dp}{dc} = \frac{\partial r'(\bar{s})}{\partial c} = 0$, the above can be re-written as:

$$\frac{\partial \pi'(\overline{s})}{\partial c} = \frac{\partial r(\bar{s})}{\partial c} p_s(\bar{s}) - \alpha \frac{dr(\bar{s})}{dc} p_s(\bar{s}) \frac{d\sigma}{dp}$$

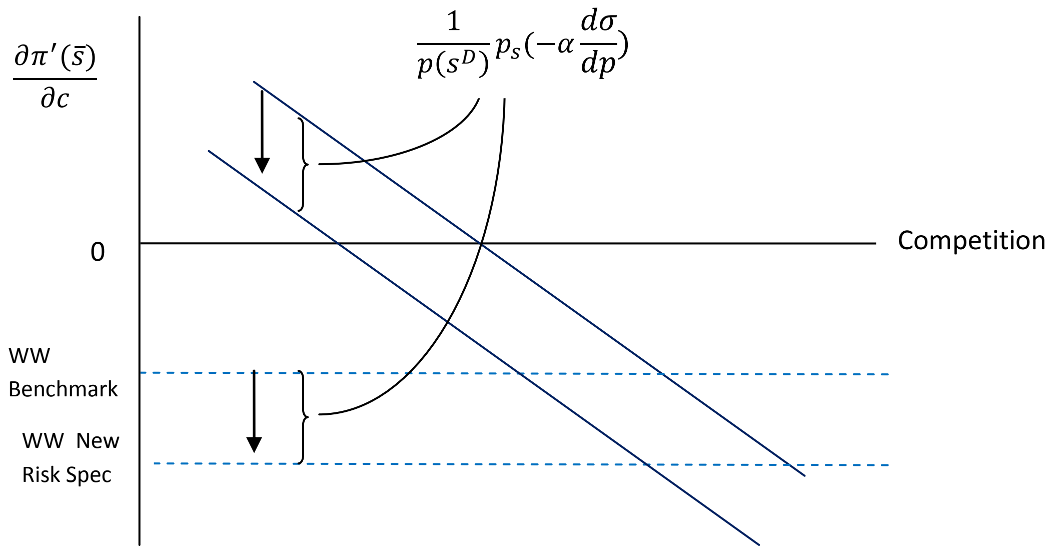
because $\frac{\partial r(\bar{s})}{\partial c} = \frac{1}{p(s^D)}$ the above simplifies to the following:

$$\frac{\partial \pi'(\overline{s})}{\partial c} = \frac{1}{p(s^D)} \left[1 - \alpha \frac{d\sigma}{dp}\right] p_s(\bar{s}) < 0 \qquad (6.13)$$

From 6.13, it is clear that risk aversion induces a bank to respond to a reduction in competition by an even further reduction in risk taking than the WW benchmark by a factor of $\left[1 - \alpha \frac{d\sigma}{dp}\right]$.

The results are analogous (though markedly less aesthetic) when p is specified to be a function of both r and s. Figure 2 depicts how this new specification of risk aversion changes the earlier relationships:

Figure 2: Change in Marginal Profit with respect to Competition



6.3: Analysis

Tackling the results in 6.2.2 first, it is clear that the magnitude of risk taking/reducing by the bank has been non-linearized by the introduction of endogeneity between p and r. To clarify, the term "non-linearized" means that a bank's incentive to take risk in response to competition changes magnitude depending on the level of competition. More specifically, it is clear that the above creates a relationship where risk is (to decreasing returns) increasing in competition (As oppose to WW where it is linearly increasing). The reason for this is simple: the WW effect where banks can adjust their portfolios still induces banks to take on more risk in response to increases in competition. However, the added role of interest rates non-linearly influencing the probability of success allows banks to take further liberties in the risk adjustment process. When interest rates are low (and risk is low), marginal increases in the interest rate will have smaller consequences on success probability than when interest rates are high. Accordingly, the bank's response to competition will tend to be increasing risk at a decreasing rate. This result is consistent with CVH and with the more restricted WW. The reason the non-linearity of MMR has not been reproduced is due to the fact that the relationship between loan rates and payback magnitudes has not been built into the model so that the “margin effect” does not appear.

On the topic of risk aversion, it has been shown that depending on its specification, the implications for risk taking and competition can be markedly different. In the former specification, where a bank’s expected profit function is linearly shifted down by ‘αs’, risk aversion will reduce the bank’s unconditional incentive for risk taking across all competition levels but not the relationship between competition and risk taking on the margin.

In the latter case, a variance parameter was introduced that punished banks for pursuing riskier projects. As was shown in 6.13, the bank’s risk behaviour relative to the benchmark WW case is contingent on the parameter $\alpha \frac{d\sigma}{dp}$ which is strictly less than zero. Holding alpha constant, if this term is large in absolute value it implies that a small increase in success probability will induce a large reduction in the variance parameter ‘σ’ and vice versa. Accordingly, banks will be heavily punished if they try to take on riskier projects in response to competition. As a consequence of this addendum, banks are on the margin much more concerned about risk taking in response to competition. Though this result is largely intuitive, it casts further doubt on the BDN result. This is especially true for highly risk averse banks (i.e. α is very large). Even in the case of a probability of success that depends on both r and s (the slanted line in figures 1 and 2), a large enough value of alpha (i.e. a large downward shift in figure 2) could make it so the bank will unambiguously reduce risk in response to increases in competition.

6.4: Limitations

There are several pertinent limitations/clarifications that should be discussed in recognition of the results obtained above. First, as mentioned in section 4, the above derivation assumed that the cost function of banks remains constant as competition changes. If this were not the case, the limit pricing methodology used above would cease to work and conclusions would be more ambiguous. Secondly, and as alluded to throughout the paper, the above results largely pertain to loan market competition and risk taking. Though the literature frequently refers to “bank risk taking”, it might be reasonable to suggest that the loan market contributes only partially to aggregate bank risk in the modern banking sector. Finally, policy prescriptions often use results such as the one(s) above to advocate regulating the banking sector so that competition is low. Arguments such as this often overlook the welfare consequences of low competition: interest rates will tend to be higher and deadweight loss will exist in the market for loans. Policy makers should consider whether the benefits of lower (loan market) bank risk out-weigh the cost of higher interest rates.

7-Conclusion

This paper has shown that when using switching costs as a proxy for competition and a limit pricing methodology, the BDN result that bank risk is decreasing in competition is reversed. Moreover, if the model is augmented to recognize success probability-loan rate endogeneity, the predicted relationship is non-linearized so that competition increases bank risk taking at a decreasing rate. Finally, if bank risk aversion is introduced as an increasing function of profit, the above relationship will be changed so that a given increase in competition will further increase loan market risk taking.

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