AUDITING AND BANK CAPITAL REGULATION

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Abstract

Auditing is introduced into a model of bank capital regulation. Deterministic and stochastic auditing strategies are studied. Contrary to intuition, auditing of bank risk should be focused on the safest banks because they hold the least amount of capital. Risky banks, which hold more capital, need to be audited less. The importance of auditing by regulators and penalties for non-compliance are discussed in light of the Basel II capital regulation proposals. Emphasis is placed on the importance of supervisory review - Pillar Two of Basel II - of the accuracy of banks' reports on the risk of their assets.

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1 Introduction

Capital regulations for banks are based on the idea that the riskier a bank's assets are the more capital it should hold. The international 1988 Basel Accord among bank regulators set bank capital requirements to be a fixed percentage of the face value of assets, with the only risk variation being between easily identifiable characteristics of assets, such as commercial and industrial loans versus government debt.

The revision to the Accord, commonly called Basel II, that is under consideration in many developed countries, is an attempt to improve upon the crude risk measures of the 1988 Accord. Under Basel II, banks use their internal information systems to determine the risk of an asset and then report this number to regulators.[1] In an ideal sense, the proposal is eminently sensible. After all, who knows the risks of a bank's asset better than the bank itself? But in implementation there is a serious problem. What incentive does a bank have to report the true risks of its assets?

In this paper, we argue that without adequate supervision and appropriate penalties the answer is, "Not much." Most analysis of Basel II is focused on the setting the capital requirements, commonly referred to as Pillar One of the proposal. But good capital requirements mean little if they cannot be enforced. For this reason, we think more attention needs to be focused on Pillar Two of the proposal, that is, supervisory review.[2] It is this pillar that gives supervisors the authority to enforce compliance with the rules setup under Pillar One and while not usually the focus of Basel II it is, in our opinion, fundamental to the success of the project.

These issues are examined in models where regulatory audits effect the incentives for banks to send accurate reports. By the term audit we mean the process of determining whether the reported number is accurate. In practice, our use of the term audit refers more to a supervisory exam than an external audit though the term is broad enough to incorporate this activity too.

The models have strong implications for how supervisors should deploy their limited

[1]Technically, in the proposed US implementation banks will use their internal systems to estimate a several key numbers like the probability of default and the loss given default. They then enter these numbers into a regulatory formula to determine capital requirements.

[2]The third and final pillar of Basel II is concerned with market supervision.

resources when examining banks. We find that stochastic auditing strategies are more effective than deterministic ones. Furthermore, the frequency of an audit should depend on the amount of capital held. The less capital a bank holds the more frequent the audit needs to be even if it is the safest banks that hold the least amount of capital. The reason for this counterintuitive result is that audits *prevent* risky banks from declaring that they are safe banks so the safer a bank claims to be the more frequently it is audited.

2 The Model

We want a model that illustrates the role of examinations and monitoring. The simplest model that is sufficient for our purposes is the costly state verification model of Townsend (1979). In our version, the information that may be verified is the risk of a bank's investment. We study capital regulations in four versions of the model: an idealized world where the regulator observes the bank's risk characteristics; one where the regulator does not observe the risk characteristics; another where the regulator can audit deterministically to find out the risk characteristics; and a final model where the regulator may randomly audit, that is, conduct an audit with a probability anywhere between zero and one.

The Basic Model

In the model, there is a regulator and a lot of small banks. Each bank has one investment of size one. Investments either succeed or fail. All successful investments return the same amount and all failed investments produce zero. Banks' investment projects only differ in their probability of failure. The probability of a bank's investment failing is p which lies in the range $[\underline{p}, \bar{p}]$. This probability is random to the bank and drawn from the density function $h(p)$. The cumulative distribution function is $H(p)$. Shocks are independent across banks.

A bank's investment can be financed with either deposits or capital. Banks like less capital to more. For the moment, there is no need to be specific about the details of this preference. We only need banks to want to hold less capital than the regulator wants them to. Such a desire by banks could come out of a model with a deposit insurance safety net or any model in which equity capital is costlier to raise than deposits. Let $K(p)$ be the amount of capital held by a bank with investment opportunity p. Because each bank is of size one, $1 - K(p)$ is the amount of deposits each bank holds as well as being its *utility*.[3]

The regulator cares about losses from failure and the cost of capital. We assume that the failure losses depend on the amount of deposits that the regulator needs to cover in case there is failure. This function is $V(K(p))$ with V increasing and concave ($V' > 0$ and $V'' < 0$). Because V measures losses we assume that $V(K(p)) \leq 0$ for all values of capital, with $V(1) = 0$. Figure 2 illustrates. The regulator suffers no losses from a failed bank if it has one-hundred percent capital. The purpose of this function is to generate a desire on the part of the regulator for banks with riskier portfolios to hold more capital.

The regulator also cares about the cost of capital. We assume that the per unit cost is q. This cost represents the foregone loss of liquidity services from a bank's use of capital rather than deposits.

The problem for the regulator is to choose a *risk-based capital requirement*, $K(p)$, that balances the regulatory benefit of reducing losses of failure with the costs to banks of issuing capital. This problem is the maximization problem:

$$\max_{K(p)\in[0,1]} \int_{\underline{p}}^{\bar{p}} (pV(K(p)) - qK(p))dH(p).$$

The term $pV(K(p))$ is the expected failure loss to the regulator from a bank with risks p, while $qK(p)$ is the cost to the bank of raising capital.

It is straightforward to solve this problem. We assume that the solution is interior so the first-order conditions are

$$\forall p, \;\; pV'(K(p)) = q. \tag{1}$$

The expected marginal benefit of capital is set equal to the marginal cost of capital. Equation (1) implies that $K(p)$ increases with p, that is, as the probability of failure grows the regulator increases the capital requirement. For example, if $V(K) = -(1-K)^{\alpha}$ with $\alpha > 1$ then (1) takes the simple form

$$K(p) = 1 - (\frac{q}{\alpha p})^{1/(\alpha-1)},$$

[3] A bank's preferences over K is independent of its risk p. Banks always prefer less capital to more. This assumption is strong but it simplifies the analysis in several advantageous ways.

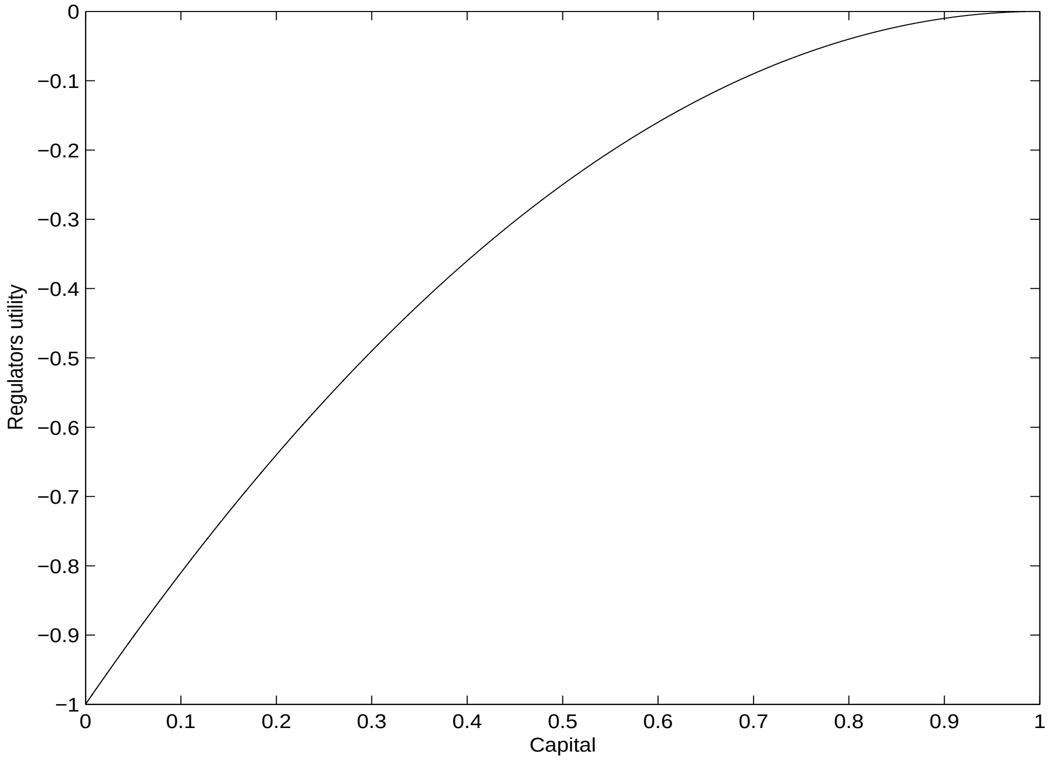

Figure 1: Example of regulator's utility from failure losses as a function of a bank's capital given p, that is, $V(K)$. The more capital a bank holds the less the loss to the regulator. The function is non-positive, increasing, and concave.

assuming q and the range of p are such that $0 \leq K(p) \leq 1$. Figure 2 illustrates. The positive relationship between default probability, p, and capital, K, is the goal of both the Basel I and II regulations.

Private information

The *fundamental* problem for Basel I and II is to determine the risk of bank assets. The premise of the Basel II reform is that banks have the best information on their own assets so that by using a bank's own internal models and data, a regulator can get a better estimate of a bank's risks than from crude measures underlying Basel I. The problem for Basel II is that banks have an incentive to understate the risk as long as they want to save on capital costs.

For illustrative purposes, we start with the extreme assumption that regulators know almost nothing about the riskiness of a bank's investment opportunities. All it knows is the distribution of these risks $H(p)$. Each bank, however, knows it own risk, that is, it has *private information.* Now, how should the regulator set capital requirements? The regulator would like to use the capital requirements in Figure 2 but that would be a disaster. Each bank would say that it was the safest bank, that is, report $\underline{p}$ to get the low capital of $K(\underline{p})$. All banks would do this and there is nothing the regulator could do afterwards. The result for the regulator would be huge losses.

Instead, the regulator should design a capital schedule that takes into account each bank's private information. The effect of private information is modeled with an incentive constraint that says a capital schedule is only feasible if it is in the interest of a bank to truthfully report its risk.[4] Formally, the incentive constraint is

$$\forall p, \hat{p}, \quad 1 - K(p) \geq 1 - K(\hat{p}),$$

or, equivalently,

$$\forall p, \hat{p}, \quad K(p) \leq K(\hat{p}). \tag{2}$$

This constraint says that the utility a bank with failure risk p receives from $K(p)$ is at least as much it would receive if it claimed to have any other failure risk $\hat{p}$.

[4]The Revelation Principle is being used here.

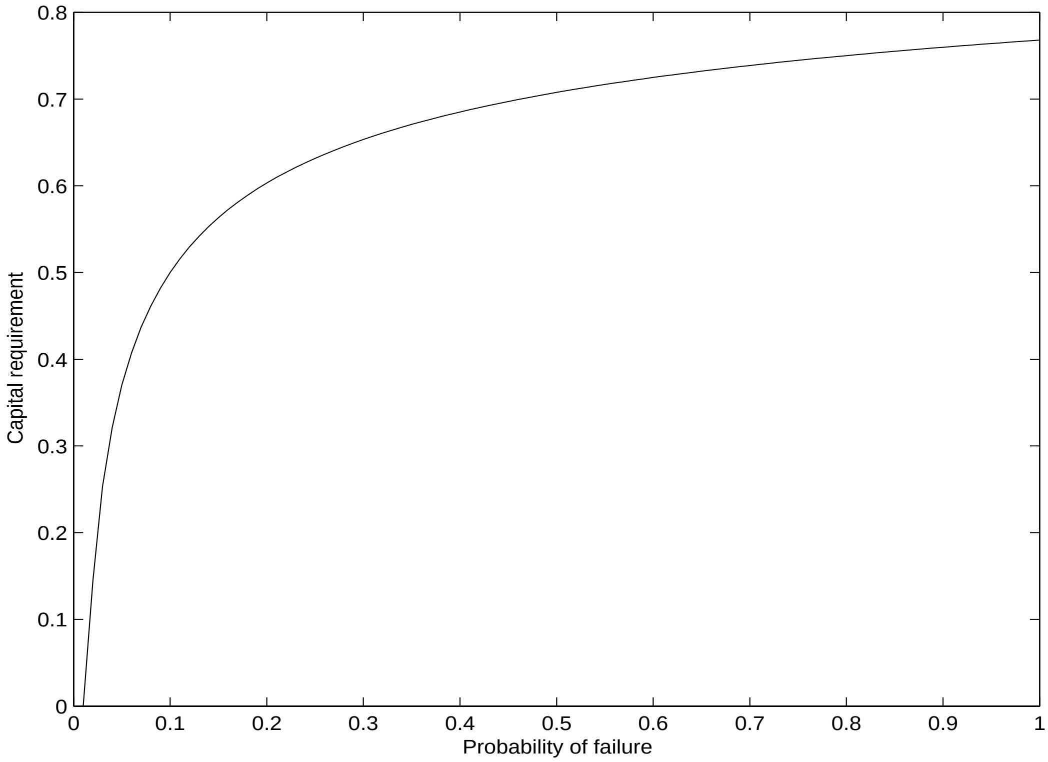

Figure 2: Optimal regulatory capital as a function of bank risk when the regulator knows a bank's risk.

The 1988 Basel Accord ...

The incentive constraint, (2), is very stringent. It eliminates most capital schedules. The *only* ones that satisfy it are those where $K(p)$ is a constant. If $K(p)$ varies with p at all, a bank assigned a higher $K(p)$ would simply claim that its assets are a risk that gets the lowest capital charge. Consequently, all bank investments must face the same capital charge, regardless of how risky their portfolio is. Indeed, this lack of responsiveness of capital charges to risk looks exactly like the Basel Accord of 1988 as applied to assets within a particular risk class. For example, a commercial and industrial loan with a ten percent chance of default is treated the same as one with a two percent chance of default.

It is precisely this equal treatment of different risks that has led to the development of Basel II. Basel II distinguishes between the riskiness of loans – the p's in the model – by allowing banks to report the risk characteristics of its loans. This is an admirable goal as represented by (1), but in light of the incentive constraint (2), it is not attainable. That constraint says there can be no risk variation in capital requirements.

Something else is needed to make Basel II work. In the next section we will see that the "something else" is audits and penalties. Unfortunately, these critical features are not usually discussed in the context of Basel II.

3 A Role for Audits

Risk sensitive capital requirements could be implemented if the regulator could gather some information about the true risk of the investments. We start with the simplest way of modeling this by allowing the regulator to observe a bank's risk characteristics if it devotes m units of resources. Other cost functions are possible. Indeed, some activities may be harder to gather information on than others. Still, the fixed cost function is the simplest to study and it illustrates the main points so we will use it.

Audits are performed after the bank reports to the regulator on the risk characteristics of its investment. For the moment, we assume that auditing is deterministic, that is, in response to a particular report the regulator must either audit or not audit. Later, we will extend the model to allow the regulator to audit with some probability.

If an audit is performed and the bank is found to have misrepresented its asset risk the regulator may impose a penalty. We model this penalty as a fixed utility amount u. The utility of a bank that is audited and is found to have lied is $1 - K(p) - u$.

The addition of audits requires a slight modification to the regulator's decision problem and to the incentive constraints. Now the regulator must decide which reports of p to verify with an audit and which to not. Let A be the region of $[\underline{p}, \bar{p}]$ for which the regulator audits and N the region for which it does not. There are two sets of incentive constraints. The first are for a bank that reports a p that does *not* lead to an audit. These incentive constraints are

$$\forall p, \;\; 1 - K(p) \geq 1 - K(\hat{p}), \;\; \forall \hat{p} \in N$$

or, equivalently,

$$\forall p, \;\; K(p) \leq K(\hat{p}), \;\; \forall \hat{p} \in N. \tag{3}$$

Incentive constraints (3) state that a bank's capital must be less than it would receive if it claimed to have a p in the no-audit region N. Like the earlier incentive constraints, (2), this incentive constraint strongly restricts feasible allocations. Now, however, the restriction only applies to p in the non-auditing region so capital must only be a constant over N. We refer to this amount of capital as K_N.

The second set of incentive constraints prevents a bank from misrepresenting itself as having a p that leads to an audit. This incentive constraint is

$$\forall p, \;\; 1 - K(p) \geq 1 - K(\hat{p}) - u, \;\; \forall \hat{p} \in A,$$

or, equivalently,

$$\forall p, \;\; K(p) \leq K(\hat{p}) + u, \;\; \forall \hat{p} \in A. \tag{4}$$

These incentive constraints are usually less important than (3). As long as u is high enough they will be automatically satisfied.

To summarize, the main difference between the earlier model and the deterministic auditing model is the severity of the incentive constraints. In the earlier model, (2) forces the capital requirement to be the same for all risks while in the deterministic auditing model (3) forces the capital requirement to be the same *only* for risks in the non-auditing region.

Even before writing out the program, two properties of optimal capital requirements can be derived. The first follows from (3). Because banks can always claim that their failure probability is some p in the non-auditing region, we know that

Proposition 1 $K(p) \leq K_N$.

The second proposition that we can prove is that the non-auditing region is convex and consists of the highest risk banks. This proposition will let us formalize the regulator's problem in a simple way.

Proposition 2 *The non-auditing region, N, is convex and consists of the highest risk banks.*

We do not provide a formal proof. Conceptually, the idea is simple. Assume that there is an audited bank that is riskier than some non-audited bank (and for simplicity both are equal fractions of the bank population). By Proposition 1 the non-audited bank holds more capital. Now, switch their regulatory requirements, that is, switch the amount of capital each holds and audit the safe bank and do not audit the riskier bank. This allocation satisfies the incentive constraints. It also increases the utility of the regulator since the capital is more effective when deployed against the risky bank than the safer bank.

These properties can be incorporated when formulating the regulator's problem. Let a be the cutoff between audited and non-audited banks. The regulator's program is

Regulator's program with deterministic auditing

$$\max_{a, K_N, K(p)} \int_{\underline{p}}^{a} (pV(K(p)) - m - qK(p))dH(p) + \int_{a}^{\bar{p}} (pV(K_N) - qK_N)dH(p)$$

subject to the incentive constraint

$$\forall p < a, \;\; K(p) \leq K_N \tag{5}$$

and (4).

For the purpose of our analysis, we are going to assume that the penalty u is high enough so that (4) does not bind. Furthermore, when we take the first-order conditions we are going to ignore the incentive constraint (5) and show that the solution to the program without it still satisfies it. This property does *not* mean that the private information does not matter in this problem. Instead, it means that setting up the problem with a cutoff between the auditing and non-auditing regions and with constant capital in the non-auditing region is enough for incentive compatibility.

The derivative with respect to K_N is

$$V'(K_N)\int_a^{\bar{p}} pdH(p) = q\int_a^{\bar{p}} dH(p). \tag{6}$$

The first-order conditions with respect to $K(p)$ are

$$\forall p < a, \;\; pV'(K(p)) = q. \tag{7}$$

Again, we assume that the solutions are interior.

Two properties of a solution follow from these two constraints. First, from (7), we know that $K(p)$ is increasing in p for $p \in A$. Second, there is a discontinuity in $K(p)$ at the cutoff a. Let $\tilde{K}(a) = \lim_{p\to a} K(p)$. Taking the limit of (7) at $p = a$ and substituting for q in (6) delivers

$$V'(K_N)E(p|p \geq a) = aV'(\tilde{K}(a)), \tag{8}$$

where

$$E(p|p \geq a) = \frac{\int_a^{\bar{p}} pdH(p)}{\int_a^{\bar{p}} dH(p)}.$$

Because a is less than the average probability of failure in N, that is, over the range a to $\bar{p}$, (8) implies that $V'(\tilde{K}(a)) > V'(K_N)$, which in turn implies that $\tilde{K}(a) < K_N$. Thus, $K(p)$ is discontinous at a. Furthermore, this result proves that constraint (5) is redundant.

The intuition for the discontinuity is that for $p \in A$, $K(p)$ is set just like in the full-information problems, where (8) is satisfied when the marginal benefit of capital equals its marginal cost. But for $p \in N$, $K(p)$ is a constant so K_N is set to equalize the *expected* marginal benefit of capital with its marginal cost. Figure 3 illustrates what a capital schedule may look like.

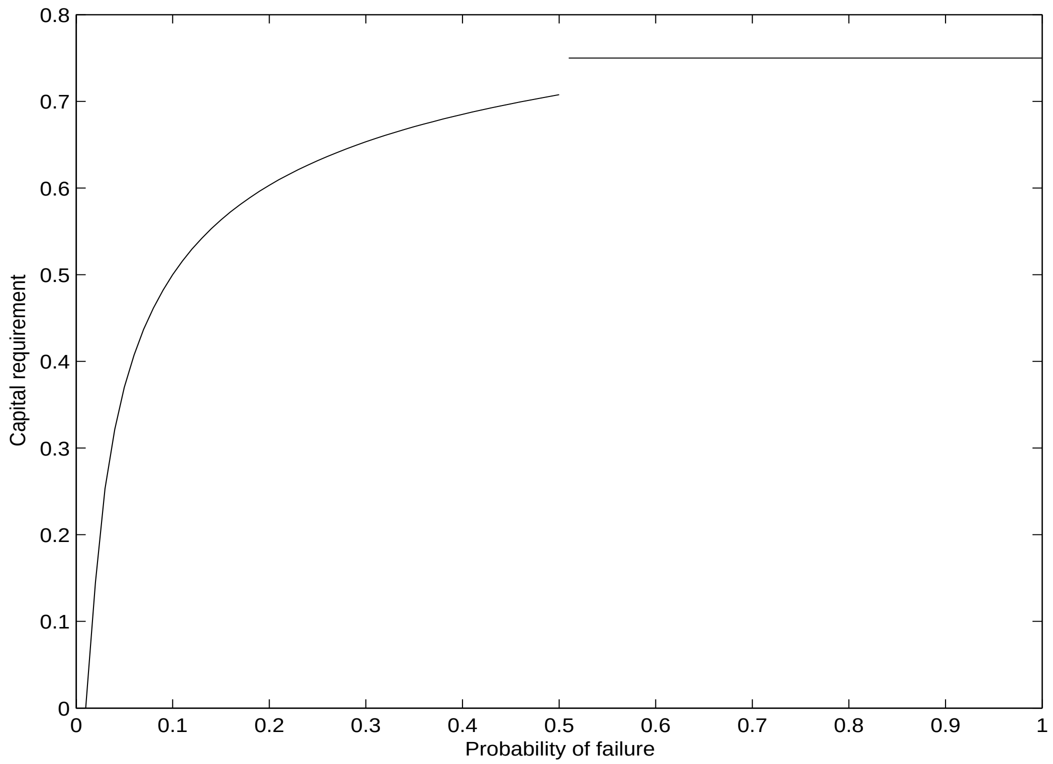

Figure 3: Optimal regulatory capital when banks' have private information about their true risks and the regulator may undertake deterministic audits. The schedule is discontinuous at the point where the regulator stops auditing banks. The horizontal portion corresponds to the capital holdings of the risky banks, that is, K_N, none of whom are audited.

The final first-order condition is taken with respect to the cutoff point a. It is

$$(aV(K_N) - (aV(K(a)) - m)) - q(aK_N - aK(a)) = 0.$$

Canceling terms and then rearranging gives

$$aV(K_N) + qK(a) + m = aV(K(a)) + qK_N. \tag{9}$$

The left-hand side of equation (9) is the marginal cost of increasing the cutoff point and the right-hand side is the marginal benefit.

Back to Basel ...

The implications for capital regulation are very strong and, at first glance, counterintuitive. It is the highest risk banks that do not need to be audited. Only banks that want to hold less capital than the maximal amount are audited. This result, however, should not be surprising since for incentive reasons there is no need to audit anyone who is willing to hold the maximal amount of capital. Indeed, if regulators have a maximum amount of risk p they are willing to allow banks to take, and assuming they have the power to shut down banks, then they would have to audit every bank that operates.

The model demonstrates just how fundamental auditing and the penalties are to regulatory policy. Risk-sensitive regulation requires auditing of any bank that holds less than the largest amount of capital. Presumably, this would include most banks so these auditing costs will likely be high. This seems problematic but, fortunately, other regulatory policies may still implement risk-sensitive capital requirements at a lower cost. In the next section, we consider a model with *stochastic* auditing that does precisely this.

Still, the point remains that auditing and penalties cannot be avoided. Basel II contains many details on how a bank should justify its capital ratio but these procedures can never be perfect. If they were we could turn over investment decisions to regulators. Basel II is premised on the belief that banks know their risks better than regulators and while regulators can gather some information on these risks they can never know as much as the bank. For this reason, the incentive concerns detailed above are unavoidable.

4 Stochastic auditing

In this section, we modify the model so that the decision to audit by the regulators can be stochastic. By this we mean that in response to a bank's risk report the regulator may audit with some probability. As we will see, this saves on supervisory resources. As before, we will assume that these audits fully reveal the information. Alternatives can be studied. For example, the regulator may only observe a signal correlated with the true risk or the quality of the signal may depend on the intensity of the audit.

Stochastic auditing requires making a few changes to the model. First, we drop the distinction between the auditing and no-auditing regions. Let $\pi(p)$ be the probability of an audit given that p is reported. As before m is the cost of an audit and u is the utility penalty that is imposed if a bank is found to have lied.

Regulator's Program with stochastic auditing

$$\max_{K(p)\in[0,1],\pi(p)\geq 0} \int_{\underline{p}}^{\bar{p}} (pV(K(p)) - \pi(p)m - qK(p))dH(p)$$

subject to the incentive constraint

$$1 - K(p) \geq 1 - K(p') - \pi(p')u, \quad \forall p, p'. \tag{10}$$

Incentive constraint (10) differs from the deterministic case incentive constraints, (3) and (4), in that $\pi(p)$ can take on any value between zero and one.

There are a lot of incentive constraints in (10) but, fortunately, most of them are redundant. Notice that utility is decreasing in $K(p)$ and utility from reporting the wrong p does not depend on a bank's risk type. This means that if the incentive constraint holds for the type with the highest capital charge – for now, assume that it is the highest risk bank $\bar{p}$ – then the incentive constraint holds for all other risk types. Formally, (10) can be replaced by

$$K(\bar{p}) \leq K(p) + \pi(p)u, \quad \forall p. \tag{11}$$

Another simplification is possible. Audits are a deadweight cost so it is best to minimize their probability. For a given capital schedule, the audit probabilities are minimized when

(11) holds at equality. Therefore,

$$\pi(p) = \frac{K(\bar{p}) - K(p)}{u}. \tag{12}$$

We hinted above that the highest risk bank would be the type to hold the greatest amount of capital. This is intuitive but it can be proven. Imagine that the bank assigned the highest amount of capital is not the highest risk one. For simplicity, assume that all types of banks occur with equal probability. Then, simply switch the capital requirement faced by the highest risk bank and the one holding the most capital. Incentive compatibility still holds and the regulator's objective function is higher since the highest risk bank holds more capital.

We could substitute (12) directly into the objective function but for optimization purposes it is more convenient to consider

$$\pi(p) = \frac{\bar{K} - K(p)}{u} \tag{13}$$

and require that $K(p) \leq \bar{K}$, for all value of p. Equation (13) will be substituted into the objective function and we will make $\bar{K}$ a choice variable. As long as the solution has $K(p) \leq K(\bar{p})$, auditing probabilities will be non-negative. Furthermore, because auditing is a deadweight cost any solution will necessarily set $\bar{K} = K(\bar{p})$. With these changes, the program is:

Simplified Regulator's Program with stochastic auditing

$$\max_{K(p)\in[0,1],\bar{K}} \int_{\underline{p}}^{\bar{p}} (pV(K(p)) - \frac{\bar{K} - K(p)}{u} m - qK(p))dH(p).$$

subject to

$$\forall p, \quad K(p) \leq \bar{K}. \tag{14}$$

Even before studying the first-order condition, the solution has the following properties from (12). First, the probability of an audit is zero for any bank that holds the highest amount of capital. Second, the audit probability increases as capital declines.

The first set of first-order conditions for this problem are

$$\forall p, \quad (pV'(K(p)) + m/u - q) = \lambda(p), \tag{15}$$

where $\lambda(p)h(p) \geq 0$ is the Lagrangian multiplier on (14) for p. The remaining first-order condition is

$$m/u = \int_{\underline{p}}^{\bar{p}} \lambda(p) dH(p). \tag{16}$$

We already demonstrated that it is only the highest risk banks that will hold the most amount of capital. Therefore, $K(p) \leq K(\bar{p})$. For any bank with $K(p) < K(\bar{p})$, $\lambda(p) = 0$ so (15) implies that capital is increasing in risk in this range.

The first-order conditions can be used to derive two additional properties of a solution:

Proposition 3 *There is a range of banks at the upper tail of the distribution (more formally a range with positive measure) that hold $K(\bar{p})$.*

This proposition is equivalent to showing that there is a range of p for which constraint (14) binds. A proof is contained in the Appendix.

The second result is different than the deterministic auditing case.

Proposition 4 *The capital schedule $K(p)$ is continuous.*

This proof is also in the Appendix.

The properties of the stochastic auditing model are illustrated with an example. We also calculated the optimal deterministic auditing contract to compare the two. The example used the following parameter values: $h(p)$ is a uniform distribution over the range $\underline{p} = 0.1$ and $\bar{p} = 0.5$, $V(K) = -1.5(1-K)^2$, $m = 0.01$, $u = 1.0$, and $q = 0.5$.

Figure 4 reports optimal capital requirements under deterministic and stochastic auditing. The schedule for the deterministic case has a discrete jump at the no audit point. The schedule for the stochastic case is continuous. In the deterministic case, there is a much bigger range of p for which capital is flat. Capital requirements are, necessarily, less finely tuned in this case. Also, for p in the audit range (roughly between 1.0 and 1.5) $K(p)$ is slightly smaller under deterministic auditing than under stochastic auditing. This difference comes from comparing the two problem's first-order conditions. Condition (15) has an additional term m/u that is not in (7). This term makes $K(p)$ higher in this range.

Figure 4 reports the audit probabilities for both models. Of course, the deterministic case probabilities are either zero or one. Probabilities for the stochastic case move

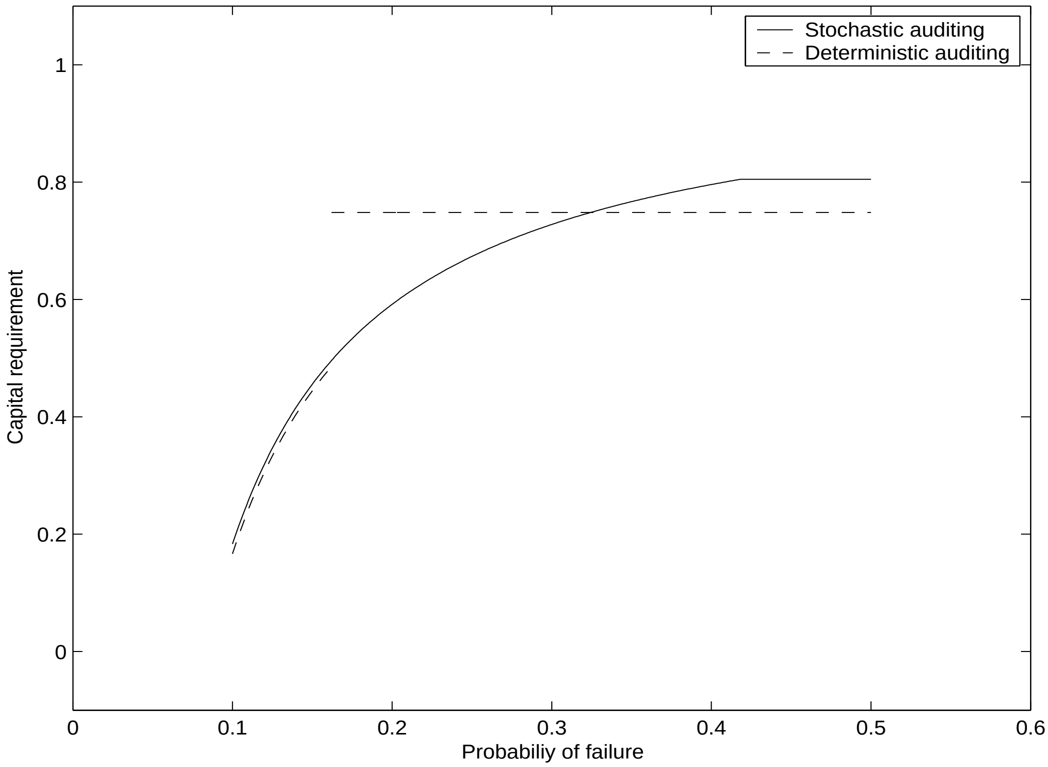

Figure 4: Optimal capital requirements in the example with deterministic and stochastic auditing. The discrete cutoff for the deterministic auditing case is the point where the regulator stops auditing. Where the regulator audits in the deterministic case the capital schedule is slightly lower for the deterministic case than in the stochastic case.

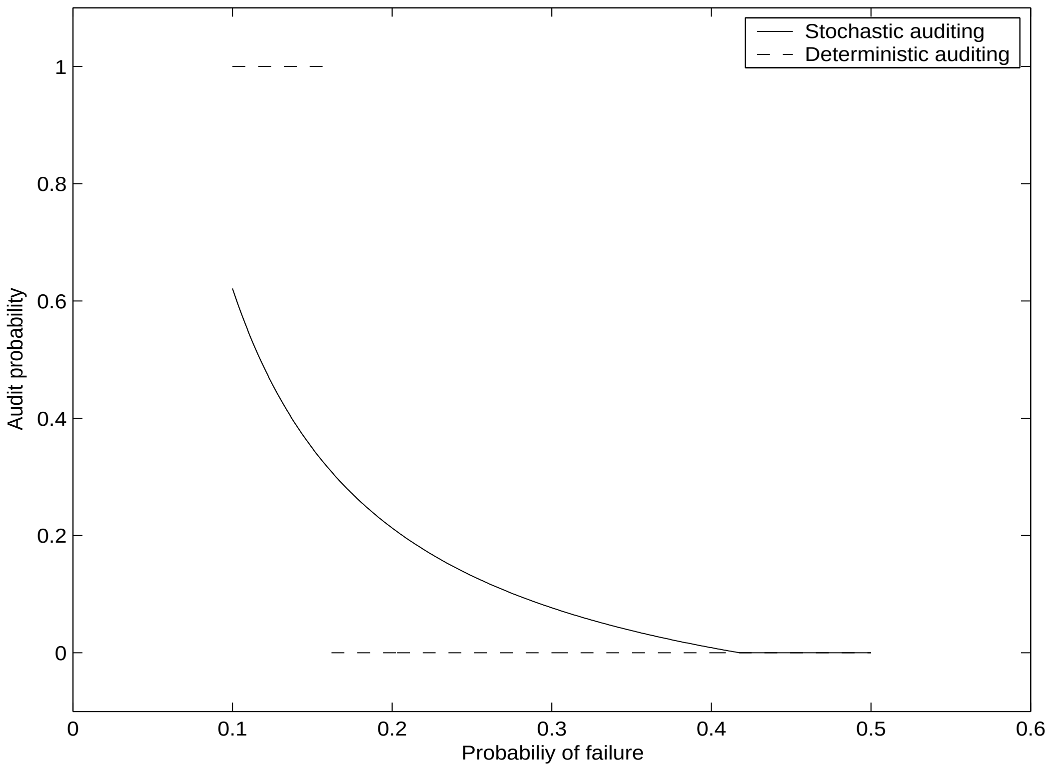

Figure 5: Audit probabilities as a function of bank risk type for the deterministic and stochastic cases. By necessity, the deterministic case probabilities are either zero or one. The probabilities vary smoothly for the stochastic case.

smoothly and hit zero for the risk types who hold the highest amount of capital. As capital declines audit probabilities increase. Finally, the stochastic auditing case saves on auditing resources. In the deterministic case, banks are audited 15.5% of the time while in the stochastic case it is 13.7% of the time.

The differences in the two types of arrangement are evident in the figures. Stochastic auditing is, of course, more efficient. Here it allows for more finely tuned capital requirements and uses less auditing resources.

5 Conclusion

Basel II is based on the premise that banks know their own risks better than regulators and this information should be used to determine regulatory capital. For this reason, it necessary to consider the incentives banks have for truthfully reporting their risks. This paper argued that the penalties or sanctions imposed for non-compliance are critical for determining these incentives. Basel II is, unfortunately, relatively silent on this issue. As Basel II is adopted and implemented these issues will have to be dealt with.

The models developed in this paper not only illustrated the role of penalties but it also illustrated various supervisory strategies for gathering information and imposing sanctions. Supervisory resources are scarce and costly. For this reason, finding the best way to deploy them is valuable. The stochastic auditing model demonstrated that randomized audits, or exams, could improve upon regular planned audits.[5]

In the models, audit frequencies and capital requirements are inversely related. Less capital requires more frequent auditing for incentive reasons. Counter intuitively, this implies that it is the safest banks that are audited the most. The reason for this regulatory behavior is that the role of audits is to prevent risky banks from claiming to be safer than they really are. Because no one wants to claim to be riskier than they actually are there is no need to audit a bank that says it is the highest risk. It has agreed to hold more capital and that is all the regulators desire.

The precise relationship between audit frequencies and capital requirements depends

[5] Audits may be made to depend on other signals. Marshall and Prescott (2001) analyzes a model where regulatory sanctions depend on the realization of bank returns.

on parameters such as available penalties, auditing costs, the costs of capital, and the distribution of bank risk types. If these parameters differ between countries, then there should be different capital schedules in each country. Harmonization of regulations is not without its costs.

The models developed in this paper necessarily left out other relevant dimensions to the problem. For example, audits are not perfect. Sometimes the information gathered is incorrect. One way to incorporate these important factors is to only allow regulators observe a signal correlated with the true state. Other possibilities include making it costly for banks to hide information, e.g. Lacker and Weinberg (1989). Another important extension is to consider dynamic capital schedules. Supervisors interact over time with banks and may have latitude to generate the equivalent of penalties through their future treatment of the bank. There is a small literature on dynamic costly state verification models that should be relevant. Papers in this literature include Chang (1990), Smith and Wang (1998), Monnet and Quintin (2003), and Wang (2003).

A Appendix

Proposition 3 *There is a range of banks at the upper tail of the distribution (more formally a range with positive measure) that hold* $K(\bar{p})$*.*

If only the highest risk bank, $\bar{p}$, holds the greatest amount of capital then $\lambda(p) = 0$ for all $p < \bar{p}$. But then $\int_{\underline{p}}^{\bar{p}} \lambda(p)h(p) = 0$, which contradicts (16). Therefore, $\lambda(p) > 0$ for a range of p with positive measure. These values of p have to be the highest risk ones. If not, consider $p_1 < p_2$ with $K(p_1) = K(\bar{p})$ and $K(p_2) < K(\bar{p})$. We know that $\lambda(p_1) \geq 0$ and $\lambda(p_2) = 0$. Using (15) we have

$$p_1 V'(K(\bar{p})) + m/u - q = \lambda(p_1) \geq \lambda(p_2) = p_2 V'(K(p_2)) + m/u - q,$$

which implies that $p_1 V'(K(\bar{p})) \geq p_2 V'(K(p_2))$. But $V'(K(\bar{p})) < V'(K(p_2))$ so $p_1 > p_2$, which is a contradiction.

Proposition 4 *The capital schedule* $K(p)$ *is continuous.*

Let $\hat{p}$ be the lowest value of p at which $K(p) = K(\bar{p})$. The capital schedule is clearly continuous above and below this point. Take the limit of $K(p)$ as p approaches $\hat{p}$ from below. Call this limit $\tilde{K}(\hat{p})$. Evaluating (15) at the limit gives

$$(\hat{p} V'(\tilde{K}(\hat{p})) + m/u - q) = 0. \tag{17}$$

If $K(p)$ is not continuous at $\hat{p}$ then $K(\hat{p}) = K(\bar{p}) > \tilde{K}(\hat{p})$, which implies that

$$\lambda(\hat{p}) = (\hat{p} V'(K(\bar{p})) + m/u - q) < 0. \tag{18}$$

But $\lambda(\hat{p}) < 0$ is a contradiction so $K(p)$ is continuous at $\hat{p}$ as well.

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