Available online at www.sciencedirect.com

SCIENCE DIRECT®

Journal of Banking & Finance 28 (2004) 1617–1635

Journal of BANKING & FINANCE

www.elsevier.com/locate/econbase

The implied reserves of the Bank Insurance Fund

Athanasios Episcopos *

Department of Economics, Athens University of Economics & Business, 76 Patission Street, Athens 104 34, Greece

Received 3 July 2002; accepted 19 May 2003
Available online 30 August 2003

Abstract

Option models of deposit insurance pricing view assessment rates as put option premiums. However, such models ignore the risk of guaranty fund default. This paper attempts to link risk-based premiums with guaranty fund reserves in a partial equilibrium setting, by employing a methodology based on options with credit risk. The value of full insurance per coverage period is expressed as a standard options premium and is decomposed into two parts. The explicit part is due to the available assets (reserves) of the guaranty fund, while the implicit part comes from federal support, contingent on the adequacy of reserves at the end of the coverage period. Implied reserves are derived under an exogenous insurance coverage rate as a policy parameter. The method is illustrated on a sample of 40 large bank holding companies and an extension to the case of several insured banks is provided.

JEL classification: G21; G13; G28
Keywords: Deposit insurance; Federal Deposit Insurance Corporation; Reserves; Credit risk

1. Introduction

Merton (1977) used an analogy between options and deposit insurance to determine actuarially fair premiums as European put options on insured bank assets. The main implication of the options approach was that premiums would depend on the relative size of insured deposits to assets and, more importantly, on bank asset risk. This was in contrast to the uniform premium policy followed by the Federal Deposit Insurance Corporation (FDIC) since the FDIC's inception. Later papers in the

* Tel.: +30-210-8203364; fax: +30-210-8203301.
E-mail address: episcopos@aueb.gr (A. Episcopos).

0378-4266/$ - see front matter
doi:10.1016/S0378-4266(03)00140-7

same strand of literature included Merton (1978), Marcus and Shaked (1984), Ronn and Verma (1986, hereafter, RV), Pyle (1986) and Allen and Saunders (1993) in banking, and Cummins (1988) in insurance guaranty funds. The options model stands as a theoretical benchmark for risk-based deposit insurance pricing, despite its practical shortcomings, such as the difficulty of estimating the unobserved market value of bank assets.

The Banking and Savings and Loan crises of the 1980–1994 period, during which more than 1600 banks and 1300 S&Ls failed, raised important questions about regulation and supervision, particularly about the solvency of guaranty funds. After a series of regulatory responses to the crises, Congress passed the FDIC Improvement Act (FDICIA) in 1991. Regarding insurance pricing, a mandate of the FDICIA was the creation of a risk-based system in determining assessment rates. Regarding reserves, the FDIC was since required to maintain a designated reserve ratio (DRR) of 1.25% of total insured deposits for the Bank Insurance Fund (BIF) and the Savings Associations Insurance Fund (SAIF) by raising premiums. This specific DRR was a remnant of the Depository Institution Deregulation and Monetary Control Act of 1980 and was originally based on the historical average of the reserve ratio. However, there has been no theoretical backing of this figure and some have even questioned the very practice of targeting fund reserves (Pennacchi, 2000).

The issue of BIF capital adequacy is an important problem that has yet to be solved in a satisfactory way, but has been addressed by actuarial models using the distribution of losses from bank failures (e.g., Sheehan, 1998; Kuritzkes et al., 2002). The broad conclusion out of these studies is that the BIF reserves are adequate. However, a limitation shared by such approaches is their heavy dependence on past BIF losses. Even though the number of bank failures is sufficient for simulations, the number of distinct major incidents and crises is very limited. Furthermore, one can argue that loss distributions have changed, especially due to the wave of mergers after 1995, following the deregulation of banking. In fact, recent evidence indicates that systemic risk potential in the financial sector has increased in the last decade due to consolidation (De Nicolo and Kwast, 2002). Portfolio diversification may have reduced the probability of large bank failures but severity has increased and loss history is not the best guide anymore.

In search of an options model connecting premiums with fund reserves, let us first make some observations. Although insured deposits are government backed, full coverage of depositors by the BIF reserves alone is impossible. There is always a small but distinct probability that extra funds will be needed, at least in a major crisis, and this has been amply demonstrated during the 1980–1994 period. Actually, we can think of the total guarantee provided as coming from two sources: (a) The tangible assets of the fund; these are essentially current fund reserves that include prepaid premiums in each period, (b) All other government support of the BIF. If we assume that federal injections to the fund are contingent on the depletion of the fund at the end of each insurance period, then it is natural to question the creditworthiness of the existing reserves *in the short run*.

To fix the last point, consider a hypothetical actuarial example: Suppose a property–casualty insurer has put aside $100, exclusively designated to cover a set of earthquake risks for a given period. Suppose earthquake strikes and requires \$120 to reimburse policyholders. The company would need to use these reserves and contribute an additional \$20 (perhaps this \$20 would come from a coinsurance arrangement). Of course, a proper action would be to garner an additional \$100 to restore the funds, in order to maintain the same level of coverage in the next period. Suppose the insurer can meet this requirement in all likelihood. Thus, although the company may be creditworthy regarding earthquake risks, the specific reserves themselves may be inadequate in each period.

It is clear from the above how the issue of limited coverage by the BIF reserves arises, even though the FDIC has the credit rating of the US government in the long run. The coverage value provided by the fund's available assets or reserves can be captured by the so-called "vulnerable" options, that is, options with default risk on the part of the option writer. A partial literature on these options includes Johnson and Stulz (1987, hereafter JS), Jarrow and Turnbull (1995), Hull and White (1995), Klein (1996) and Klein and Inglis (2001) and we can turn to that field for answers.

In this paper, the following methodology is proposed: Suppose that a single bank is insured by the reserves, V, of a guaranty fund, and that markets are sufficiently complete. Suppose also that government support is contingent on the adequacy of the reserves at the end of the insurance period. Then, the premium under credit risk would be a vulnerable put, $p(V, \theta)$, which is a function of the fund assets and a set of parameters, θ, including the volatility of bank asset returns. That premium is the value of limited coverage insurance. The value of full coverage insurance is given by the standard premium, P, derived from a reference options model, such as RV, adjusted for recent developments in regulation. Setting the coverage ratio, p/P, to an exogenous level targeted by policy makers, one can extract the implied fund level associated with such coverage. Extension to several banks is straightforward.

The proposed approach extends the options models of deposit insurance pricing by incorporating the credit risk of the guaranty fund, and provides the desired linkage between premiums and reserves. Thus, we can speak of an isomorphism between deposit insurance and options under credit risk, while standard option models of deposit insurance hold as a limiting case when credit risk is absent. A useful implication for policy is that we now are able to determine which part of the provided insurance is tangible and which part is not. This result can help in quantifying the marginal cost of switching between implicit and explicit insurance, that is, allocating guarantor assets between reserves and back-up support. The paper is not intended to provide specific estimates of the optimal BIF reserves for the whole banking system, but rather to illustrate a new methodology on a limited number of banks. It is shown, however, that finding estimates of the actual BIF reserves is feasible.

From a technical point of view, the paper is based on the aforementioned literature on options with credit risk. Unlike these models, the paper uses non-stochastic option writer assets, but, in effect, extends that literature to the case of several European put options.

The rest of the paper is organized as follows: Section 2 presents the standard and limited-coverage options models of deposit insurance, under the assumption that a single bank is insured. Section 3 discusses the data used in the analysis, which includes a sample of 40 large bank holding companies (BHCs). Section 4 gives estimates of the required reserves to insure a single bank, Section 5 provides the extension to the case of multiple banks, and Section 6 concludes.

2. The implied guaranty fund reserves under credit risk

2.1. Full coverage

The RV version of the options approach uses the analogy between European put options and deposit insurance, and call options and equity. The term of deposits and other liabilities can be considered as the time to next audit of the bank in order to set the new insurance premium. In a simplified set up using essentially the assumptions of the Merton (1977) model, asset values are not affected by financial distress, and dissolution of the firm's assets is costless. In addition, the existence of deposit insurance makes deposit claims grow at the risk free rate. If depositors and other creditors have equal seniority in the event of default by the bank, depositors would receive either their full claim or a proportion of the liquidated assets of the bank.

For the present model, we assume that bank assets follow correlated lognormal diffusions. Let us start with some notation:

S	unobserved, asset value (excluding deposit insurance) of a bank insured by the FDIC
E	market value of the bank's equity
D	the bank's insured domestic deposits
L	total liabilities of the bank
k	$D/L =$ deposits as a proportion of total liabilities
V	pre-insurance market value of the fund assets without government support. It includes current period premiums
T	time to next FDIC audit of the bank and insurance repricing
σ_E	volatility of equity
σ_i	unobserved asset volatility of the ith bank, $i = 1, 2, \ldots$
$\rho_{i,j}$	unobserved correlation coefficient between asset returns of banks i and j
r	the risk free rate assumed to be constant for all maturities
N	the standard normal cumulative distribution function
f_n	the n-variate standard normal density function

Subscripts with respect to T will denote asset values at the assumed time of debt maturity, otherwise the variables are with respect to time zero. In this exposition, we ignore dividends to simplify the notation. However, this assumption is unlikely to affect results, because dividends in our sample (discussed in Section 2 below) are only about 0.4% of bank assets. L, D and V grow at the risk free rate: The first by assumption, the second due to the guarantee, and the third because the FDIC invests most of the BIF reserves in Treasury obligations. The ratio k is invariant within each period. In addition, as explained in RV, the value of the deposit insurance is taken out of the assets when computing equity. Thus, it is post-insurance value that matters for such calculations.

The value of full deposit insurance can be found by discounting the expected insurance payoffs:

$$\begin{aligned} P &= \mathrm{e}^{-rT} E_1\{\max(D_T - S_T k, 0)\} \\ &= \mathrm{e}^{-rT} E_1 \left\{ \begin{matrix} D_T - S_T k & S_T < D_T/k \\ 0 & \text{otherwise} \end{matrix} \right\}, \end{aligned} \tag{1}$$

where E_1 denotes the risk-neutral expectation over the bank assets. There are at least two ways to compute P. One is to recognize, as did RV, that the premium is a put option on the firm's assets, S_T, with an exercise price the future value of total liabilities, L_T, scaled down by the proportion of insured deposits to total liabilities. The dollar premium would then be given by the following:

$$P = D(N(y + \sigma_1\sqrt{T}) - (S/L)N(y)), \tag{2}$$

where

$$y = \frac{\ln(L/S) - \sigma_1^2 T/2}{\sigma_1\sqrt{T}}. \tag{3}$$

Another way the RV premium can be formulated is by translating the payoffs of Eq. (1) into integrals:

$$P = \frac{\mathrm{e}^{-rT}}{\sigma_1\sqrt{T}} \left[\int_0^{D_T/k} \frac{D_T - sk}{s} f_1 \, \mathrm{d}s \right], \tag{4}$$

where f_1 is the density of the standard normal (the density under risk neutrality). Eq. (4) will be useful when extending the model to the multiple bank case below.

It is understood that the RV model is a simplification because, in a real bank situation, liabilities come in many forms. They range from deposits and interbank borrowing to the most exotic cases of leverage, such as options written by the bank. Certainly, real debt is not term debt the way the model assumes. Furthermore, the contingent claims approach, essentially Merton's (1974) credit risk model and its extensions, has received some criticism in the literature on empirical grounds (Jones et al., 1984), although sometimes the evidence is mixed or supportive of option models of credit risk (Anderson and Sundaresan, 2000). However, this paper is concerned with illustrating a new method using options. Investigating the extent of the possible error stemming from the new approach requires the development and comparison of alternative models, a task beyond the scope of this paper.

The premium formula requires estimates of the market value of the bank's assets and its volatility, both of which are unobserved. RV express equity as a call option on the assets of the firm, while total liabilities at their maturity stand in place of the exercise price. Direct assistance is also modeled by assuming that the FDIC will refrain from liquidating the bank, unless the bank asset value drops below a critical level. Such level is a proportion c of the total liabilities ($c \leqslant 1$). Then, equity can be given from the following call option:

$$E = SN(x) - cLN(x - \sigma_1\sqrt{T}), \tag{5}$$

where

$$x = \frac{\ln(S/cL) + \sigma_1^2 T/2}{\sigma_1\sqrt{T}}. \tag{6}$$

However, subsequent legislation through FDICIA and the Omnibus Budget Reconciliation Act of 1993 imposed a least-cost principle on the FDIC in bank resolutions and prohibited the use of FDIC money for open assistance, unless a systemic risk reason were agreed upon by the top three national regulators. This means that c should be set to unity and, therefore, this assumption is adopted in the rest of the paper. The volatility of assets is

$$\sigma_1 = \frac{\sigma_E E}{SN(x)}. \tag{7}$$

Using the observed value for equity and the nominal value of deposits and other liabilities, as well as the estimated parameters, we can solve the last two equations numerically, with $c = 1$, to arrive at estimates for the current value of the assets and its volatility.

Although the RV model has been the standard for computing deposit insurance with options, it is not immune to further criticism. In particular, the Omnibus Budget Reconciliation Act of 1993 set a priority of claimants in bank failures. In the event of a bank failure, the claims priority in a receivership was as follows: Receivership administrative expenses, secured creditors, depositors including the FDIC in the place of insured depositors, general creditors, subordinated creditors, and, finally, shareholders. The implication of this legislation, if taken literally, is that dollar premiums should be smaller, because the liability of the guaranty fund would be smaller. However, it is unclear whether depositor preference would reduce costs to the FDIC as creditors shift funds strategically and seek protection (Osterberg, 1996). In addition, there has been no large bank failure in the USA after 1993, and it is impossible to draw any conclusions as to the applicability of the new rules. Thus, for the purposes of this paper, the RV model will be employed.

2.2. Limited coverage

Suppose a single bank is insured by the fund for a coverage period. If there is any need for government support, it can take place only at the end of the period, that is, at time T. Define the fund's available assets as those assets that the fund can use to pay for damages at time T, without relying on government support. These available assets are essentially reserves (the two terms will be used interchangeably), and their value is the sum of two components, $B(q)$ and $P(q)$, where $B(q)$ is the observed level of reserves before the collection of current premiums, $P(q)$. Both depend on the government/FDIC policy, q, which is revealed at the start of the coverage period and is explained below. The initial reserves, along with the observed premium receipt, are invested at the risk free rate until time T, when the contract expires.

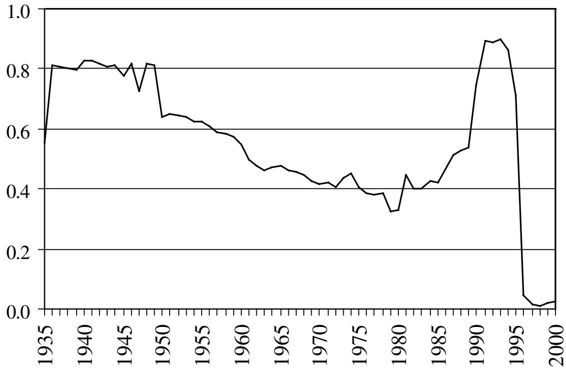

Fig. 1. BIF annual income from net premiums as a proportion of total income (1935–2000).

The government/FDIC policy determines, first, the nature of premiums (risk-based or flat, conditional on the DRR, including refunds to banks, etc.); second, the extent of government contributions and the allocation of V between $B(q)$ and $P(q)$. The decade 1990–2000 was an instructive period regarding the variety of policy manifestations. For instance, premiums increased rapidly after the FDICIA, taking the BIF from a negative balance to one satisfying the DRR in 1995. Then, according to the Deposit Insurance Funds Act of 1996, well-capitalized banks (the majority of insured banks) were exempt from contributions to the BIF. Thus, most of the fund's income was subsequently derived from interest on Treasuries (Fig. 1).

In the partial equilibrium setting above, the fund's available assets are strictly separated from government support in the short run. Various situations can be handled in this setting. For example, in the hypothetical case in which the guarantor has issued bonds, the present value of each period's interest liability would be deducted from V. Similarly for the ability of the BIF to borrow from the Treasury. Other assets and liabilities of the fund of minor importance can either be ignored or be used to adjust V. The main point, though, is that reserves are subject to credit risk in the short run even though the BIF has the credit rating of the US government in the long run. This is basically the property–casualty insurer example of the Introduction. Note also that the value of reserves should not be confused with the value of the BIF as a theoretical firm. The former is observed but the latter is not.

Having defined the fund's available assets or reserves, we can turn to debt guarantees. Debt guarantees have been examined in JS as a special case in their seminal paper on vulnerable options. By analogy with Eq. (1), the value of the deposit guarantee would be provided by the following:

$$\begin{aligned} p &= \mathrm{e}^{-rT} E_1\{\min(V_T, \max(D_T - S_T k, 0))\} \\ &= \mathrm{e}^{-rT} E_1 \left\{ \begin{matrix} D_T - S_T k & S_T < D_T/k, & V_T \geqslant D_T - S_T k \\ V_T & S_T < D_T/k, & V_T < D_T - S_T k \\ 0 & & \text{otherwise} \end{matrix} \right\}. \end{aligned} \tag{8}$$

The payoff function at time T is explained in the first line of Eq. (8). If the bank fails, depositors will get either the full insurance that is due to them, i.e., $\max(D_T - S_T k, 0)$, or they will just distribute the available assets of the fund, V_T, among themselves. The second line is more detailed: The top line in the brackets gives the terminal payoff to the insured if the bank defaults and the fund's assets are sufficient to cover the resulting liability. The payoff is identical to that of Eq. (1). The second line in the brackets gives the payoff to depositors if the fund is not sufficient to cover the deposit insurance liability.

Let us put this information into integrals, by analogy with Eq. (4). The limited coverage premium, p, will be given by the following:

$$p = \frac{e^{-rT}}{\sigma_1 \sqrt{T}} \left[\int_0^\infty \frac{\min(V_T, \max(D_T - sk, 0))}{s} f_1 \, ds \right]. \tag{9}$$

We know from JS that vulnerable options cannot be worth more than standard options. Thus, $p \leqslant P$. Of course, we expect that the limiting case of equality in the premiums will be rare. However, the lower value of the vulnerable premium is *not* to be interpreted as a recommendation that banks should pay less insurance. The new premium reflects the explicit value of insurance service provided by the current reserves, just as the premium in many insurance policies depends on the policy coverage. The difference between P and p gives the value of the implicit guarantee provided per period. The actual premium paid by the bank, $P(q)$, should be equal to the value of the received service, that is, equal to the RV premium, although this is not a strict requirement.

In practice, it has never been necessary or feasible to eliminate the implicit part of the insurance by strengthening the BIF. Such a task would require reserves at least as high as the insured deposits outstanding in the system. The value of a marginal dollar tied in fund reserves becomes prohibitively high after a point and this has been recognized in long-standing debates between bankers and regulators. A mandate of current deposit insurance regulation is a specific DRR for the BIF, implying some built-in target coverage. It would be useful to quantify that notion.

Motivated by this discussion, let us define the metric

$$\alpha = \frac{p(V, \theta)}{P}, \tag{10}$$

as the coverage provided by the guarantor assets, V, where θ is a set of other parameters to become obvious later. [1] Inspired by the implied volatility literature, we derive implied values for V by fixing α at some specific level, say, 90%.

Let us briefly compare the new method with RV. The original options approach to deposit insurance was meant to introduce some market-based method to assess the insurance premium by accounting for the risk of each bank. The vulnerable options approach is meant to account also for the guarantor credit risk. Combining the

[1] The word "coverage" is justified: The value of a European put providing α times the standard payoff equals α times the value of the standard option. Hence, the term, borrowed from insurance contracts.

two in Eq. (10) links risk-adjusted premiums with reserves. By extension of the Merton (1977) and RV models, the new approach introduces an isomorphism between vulnerable options and deposit insurance, with RV holding as a special case when credit risk is immaterial.

The procedure described contributes in the effort to find the optimal BIF reserves, as well as the optimal allocation of guarantor assets between reserves and federal support. It is important, however, to remember that the fair market value of the options above rests on the assumption of market completeness. The operation of the guaranty fund is different from the operation of a financial institution writing the insurance put. In the latter case, the institution would delta-hedge the risk by artificially replicating the option, i.e., using borrowing and lending and trading the equity of the firm purchasing the protection. In contrast, the fund invests its reserves in risk free assets while pooling the default risks. Let us now turn to a brief discussion of the sample.

3. Data and variables

The sample consists of 40 US chartered BHCs ranking in the top 50 BHCs in terms of asset size and includes only public companies. The sample companies account for about 55% of domestic deposits held by BIF-member commercial banks in 2000. The market value of equity was calculated by multiplying price per share with the number of common shares outstanding at 12/31/2000. Sources for these variables were Reuters and 10-K reports filed with the Securities and Exchange Commission. Total liabilities and deposits are taken from FR Y-9 reports filed with the Federal Reserve Board. The percentage of insured domestic deposits is provided by the FDIC. The FDIC derives these estimates by adding the dollar value of deposits in accounts less than \$100 thousand and the number of accounts that are larger than \$100,000 times \$100,000.

The volatility of equity is computed from daily data covering 2000. This is taken for uniformity purposes because companies were much transformed by mergers in the decade 1990–2000, and it would be difficult to have a meaningful measure of the true σ_E, if we took a larger period. Besides, it may be more appropriate to use a recent volatility measure for companies, as did RV, because it would reflect the current risk composition of the companies' assets. Summary information on the basic variables is reported in the first seven columns of Table 1. Wachovia was a company that needed separate treatment. The original Wachovia merged with First Union in September 2001 and, therefore, figures for this entry in Table 1 are adjusted appropriately using weighted sums.

The average correlation coefficient among daily stock returns of the 40 BHC's was 0.54 in 2000, and will be used below as a proxy for the assets correlation coefficient, $\sigma_{i,j}$ in numerical calculations. The Average Bank Holding Company (ABHC) is defined as the average company in the sample, that is, one with the average equity value, liabilities, deposits, and other characteristics, as per Table 1. The correlation between any two ABHCs is taken to be 0.54, the average in the sample. This assumption is

Table 1
Basic data and results on the sample of forty bank holding companies at 12/31/2000

Bank holding company	Market value of common equity	Face value of total liabilities	Domestic deposits	Percent insured	Volatility of equity	Volatility of assets	Market value of assets
Citigroup, Inc.	256,447	836,004	79,207	49.76	0.40	0.09	1,092,392
J.P. Morgan Chase & Co.	87,626	673,010	145,303	41.69	0.46	0.05	760,488
Bank of America Corporation	74,025	594,563	310,700	69.97	0.46	0.05	668,461
Wachovia Corporation[a]	38,572	306,570	175,834	67.48	0.44	0.05	345,096
Wells Fargo & Company	95,484	245,938	162,486	71.17	0.40	0.11	341,406
Bank One Corporation	42,479	250,665	142,110	60.80	0.45	0.07	293,092
FleetBoston Financial Corporation	34,069	163,347	82,331	60.88	0.49	0.09	197,343
SunTrust Banks, Inc.	18,665	95,257	59,815	68.90	0.42	0.07	113,911
The Bank of New York Company, Inc.	40,898	70,962	28,559	42.47	0.48	0.18	111,835
National City Corporation	17,514	81,765	51,535	80.56	0.41	0.07	99,272
U.S. Bancorp	17,485	78,696	52,613	65.80	0.51	0.09	96,132
KeyCorp	11,851	80,542	44,919	67.34	0.43	0.06	92,383
The PNC Financial Services Group, Inc.	21,188	63,260	45,404	69.90	0.41	0.10	84,442
State Street Corporation	10,043	66,036	11,987	3.96	0.51	0.07	76,044
Mellon Financial Corporation	23,941	46,412	33,018	45.72	0.47	0.16	70,340
BB&T Corporation	14,988	54,554	35,626	74.67	0.39	0.08	69,539
Fifth Third Bancorp	27,823	40,966	26,383	65.19	0.44	0.18	68,784
Northern Trust Corporation	18,120	33,560	12,828	42.40	0.53	0.19	51,652
Comerica Incorporated	9,319	38,025	26,531	53.01	0.40	0.08	47,341
Regions Financial Corporation	6,002	40,452	28,813	73.63	0.40	0.05	46,452
SouthTrust Corporation	3,439	41,794	27,351	65.80	0.46	0.04	45,226
AmSouth Bancorporation	5,701	36,155	25,986	79.07	0.45	0.06	41,848

Union Planters Corporation	4,817	31,801	23,113	84.37	0.38	0.05	36,617
UnionBanCal Corporation	3,832	31,958	24,904	44.32	0.63	0.07	35,728
M&T Bank Corporation	6,341	26,249	19,988	77.95	0.31	0.06	32,590
Huntington Bancshares Incorporated	4,061	26,233	19,369	79.14	0.46	0.06	30,287
Popular, Inc.	3,578	26,064	14,611	74.08	0.38	0.05	29,641
Marshall & Ilsley Corporation	5,228	23,836	16,811	68.23	0.40	0.07	29,062
Zions Bancorporation	5,438	20,159	14,932	66.41	0.53	0.11	25,579
Compass Bancshares, Inc.	2,888	18,543	14,057	70.78	0.44	0.06	21,428
Synovus Financial Corp.	7,668	13,491	11,162	61.53	0.37	0.13	21,158
First Tennessee National Corporation	3,726	17,172	12,190	54.93	0.56	0.10	20,876
National Commerce Financial Bancorporation	5,080	15,358	12,057	72.81	0.46	0.11	20,434
BancWest Corporation	3,254	16,468	13,868	65.64	0.45	0.07	19,718
Banknorth Group, Inc.	2,816	16,903	12,114	81.49	0.50	0.07	19,711
North Fork Bancoporation, Inc.	3,950	13,627	9,035	79.56	0.38	0.09	17,577
Hibernia Corporation	2,011	15,218	12,064	68.34	0.40	0.05	17,228
Associated Banc-Corp	2,008	12,160	9,292	78.92	0.41	0.06	14,167
Pacific Century Financial Corporation	1,408	12,725	6,500	74.26	0.52	0.05	14,127
The Colonial BancGroup, Inc.	1,186	10,984	8,135	80.20	0.42	0.04	12,169
Total	944,968	4287,482	1863,540				5232,410
Average	23,624	107,187	46,589	65.08	0.45	0.08	130,789
Average BHC[b]	23,624	107,187	46,589	65.08	0.45	0.08	130,789

Figures in million dollars except for volatility and percent. Companies are ranked by market value of assets.

[a] Includes First Union.

[b] The average holding company in the sample.

legitimate from a statistical point of view and will speed up calculations in the case of multiple banks.

Inspection of FDIC's Annual Reports from 1998–2000, reveals that most of the reserves were invested in Treasury obligations. The average duration of the BIF's Treasuries portfolio was about 4.5 years. Thus, the assumption that reserves grow at the risk free rate is a reasonable approximation.

4. Risk-based premiums and the implied guaranty reserves

Following RV, Eqs. (5) and (7) are solved numerically for the market value of the assets and the asset volatility. Results are shown in the rightmost two columns of Table 1. These results are then used to compute the assessment rate for each BHC. The second and third columns of Table 2 show the RV premiums from Eq. (1) in cents per \$100 of deposits (basis points) and in million dollars. The average premium in the sample is 2.9 basis points. The average annual premium in RV's sample of 43 large banks was 8.1 basis points, but no meaningful conclusions can be drawn, due to the different samples used. As pointed out by RV, there may be a downward bias if some holding company assets were not available to creditors of the subsidiary banks. However, this would also influence the limited coverage option, implying that the coverage ratio should not be severely biased.

In Fig. 2, limited coverage premiums are cast as proportions of the RV premium to facilitate comparisons. The case of one bank is depicted with the leftmost curve labeled "1 ABHC" (the rest of the curves will be discussed in Section 5). The vulnerable premium is lower than that of RV, but approaches it asymptotically as V gets sufficiently large. The difference between the RV and vulnerable premiums, multiplied by the dollar value of the RV premium, is the value of implicit insurance provided by the fund. The implicit insurance gets progressively smaller with the fund size. It is noted that the curve in Fig. 2 has the same shape as that appearing in Klein and Inglis (2001), which related the value of a vulnerable option to the stochastic assets of the option writer. These results make financial sense, because, when the guarantor assets are large compared to the option liability, credit risk is immaterial.

Let us take the liberty to interpret the explicit insurance service as output and the guaranty capital as input in the value function of Fig. 2. Then, at low levels of V, the "productivity" of insurance capital is high but with diminishing returns. This is an important issue for policy makers if the model ever becomes part of a larger optimization function. Expending part of the fund to assist a failing bank or to pursue other objectives reduces the coverage level for the system. It all depends on the size of the disbursement in relation to the fund size. This is also a crucial point regarding models that examine the strength of the BIF. If a crisis absorbs, say, 30% of the fund, the remaining capital could provide less coverage than before, putting the whole system in a more precarious position.

For yet another perspective, a marginal dollar of explicit insurance corresponding to a high coverage level has a high incremental cost compared to a situation of low coverage (symmetrically for implicit insurance). The implications of these arguments

Table 2
Value of full insurance and implied reserves

Bank holding company	Value of full insurance[a] (individual RV premium)		Implied fund reserves[b] (in million dollars)			
	In cents per $100 of deposits	In million dollars	$\alpha = 99\%$	$\alpha = 90\%$	$\alpha = 70\%$	$\alpha = 50\%$
Citigroup, Inc.	0.7	2.8	4,096	2,235	1,225	722
J.P. Morgan Chase & Co.	2.2	13.4	4,126	2,263	1,247	737
Bank of America Corporation	2.2	46.8	14,236	7,819	4,308	2,546
Wachovia Corporation	1.5	17.7	7,343	4,007	2,202	1,300
Wells Fargo & Company	0.6	7.5	13,906	7,599	4,172	2,460
Bank One Corporation	2.1	17.7	7,007	3,841	2,116	1,250
FleetBoston Financial Corporation	4.5	22.5	5,387	2,993	1,659	984
SunTrust Banks, Inc.	1.1	4.7	3,359	1,834	1,007	594
The Bank of New York Company, Inc.	3.4	4.1	2,341	1,313	732	435
National City Corporation	0.9	3.9	3,491	1,904	1,043	615
US Bancorp	6.3	21.8	4,138	2,311	1,285	763
KeyCorp	1.3	3.9	2,049	1,117	614	362
The PNC Financial Services Group, Inc.	0.9	2.9	3,615	1,982	1,088	642
State Street Corporation	5.4	0.3	57	24	13	8
Mellon Financial Corporation	3.0	4.5	2,684	1,498	833	494
BB&T Corporation	0.5	1.5	2,468	1,344	736	433
Fifth Third Bancorp	1.2	2.1	3,159	1,759	973	576
Northern Trust Corporation	8.5	4.6	1,169	663	372	222
Comerica Incorporated	0.7	1.0	1,190	683	374	220
Regions Financial Corporation	0.7	1.4	1,294	703	384	226
SouthTrust Corporation	1.7	3.0	829	454	249	147
AmSouth Bancorporation	2.0	4.1	1,578	864	476	281
Union Planters Corporation	0.4	0.8	1,107	604	329	194
UnionBanCal Coiporation	19.3	21.3	1,149	652	366	219
M&T Bank Corporation	0.0	0.0	1,390	1,178	266	156
Huntington Bancshares Incorporated	2.4	3.7	1,198	659	363	215
Popular, Inc.	0.4	0.4	537	310	169	99
Marshall & Ilsley Corporation	0.7	0.8	1,579	514	281	166
Zions Bancorporation	8.9	8.8	1,436	806	450	268

Table 2 (*continued*)

Bank holding company	Value of full insurance[a] (individual RV premium)		Implied fund reserves[b] (in million dollars)			
	In cents per $100 of deposits	In million dollars	$\alpha = 99\%$	$\alpha = 90\%$	$\alpha = 70\%$	$\alpha = 50\%$
Compass Bancshares, Inc.	1.6	1.6	729	400	220	130
Synovus Financial Corp.	0.2	0.1	1,964	492	269	158
First Tennessee National Corporation	12.3	8.2	907	511	286	170
National Commerce Financial Bancorporation	2.8	2.5	1,177	653	361	214
BancWest Corporation	2.2	2.0	831	456	251	149
Banknorth Group, Inc.	4.8	4.8	928	514	285	169
North Fork Bancorporation, Inc.	0.4	0.3	1,784	361	197	116
Hibernia Corporation	0.6	0.5	447	249	136	80
Associated Banc-Corp	0.9	0.6	889	276	151	89
Pacific Century Financial Corporation	5.2	2.5	348	193	107	63
The Colonial BankGroup, Inc.	0.9	0.6	815	180	98	58
Total	115.3	251.6	108,739	58,216	31,693	18,732
Average	2.9	6.3	2,718	1,455	792	468
ABHC[c]	2.5	7.5	3,045	1,676	925	547

Figures in million dollars at end 2000 unless otherwise indicated.

[a] The Ronn and Verma (1986) premium.

[b] These are the reserves that would yield a specific coverage level, α, for the particular firm. The total is for the forty BHCs in the sample and not for the whole banking system, α is the ratio of the limited coverage premium over the full coverage premium, set to the four levels shown.

[c] Results for the average BHC in the sample.

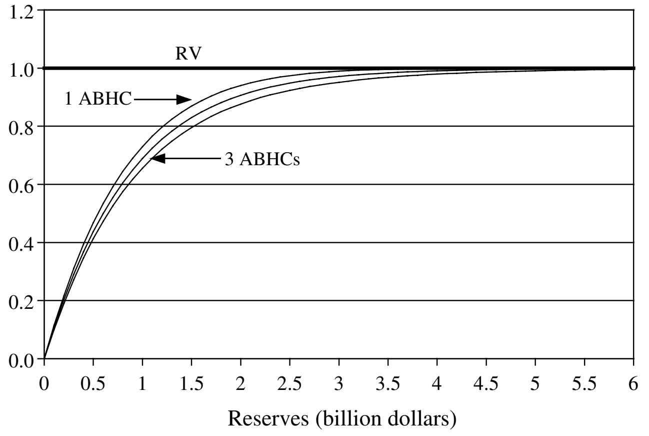

Fig. 2. Limited coverage insurance (proportion of full insurance) as a function of reserves.
Note: The fund insures *only* the specified number of ABHCs. By fixing the relative premium at a specific level on the vertical axis, we can read off the implied reserves on the horizontal axis. RV = Aggregate Ronn and Verma (1986) premium, standardized to 1.

for policy can be also seen from the following: Recently, the FDIC has made some proposals for deposit insurance reform (FDIC, 2001), including rebates to banks and fluctuating assessment rates for cyclical smoothing. If the total government guarantee is being spread over a long horizon, the new policies can be viewed as trade-offs between the implicit component of the guarantee of one period and the explicit component of another period. Of course, that would depend on the policy makers' optimization function regarding these components.

The above can also shed some light in the search for optimal fund reserves. Columns 5–7 of Table 2 display the required reserves if just one BHC is insured at a time. In a sense, these reserves could be thought as "earmarked" to perform a single insurance task. Notice the very large sums. Apparently this arrangement of exclusive use is the least economical because it does not account for the correlation among banks. A much lower fund level can insure these banks jointly. Thus, the estimates provided should be considered an upper bound to the optimal reserves for the 40 BHCs. This is an important observation because it can be extended to the multiple-bank case to determine an increasingly lower ceiling for the fund reserves. However, a more direct approach can be followed as shown in the next section.

5. Multiple banks insured

Applying the methodology above to the case of several banks is straightforward. We have to compute the multivariate analogs of the vulnerable option, p and the RV option, P. Let us express these options for the case of two banks insured by the fund. When credit risk is absent, the RV option is given by the formula:

$$P = \mathrm{e}^{-rT} E_{1,2}\{\max(D_{1T} - S_{1T}k_1, 0) + \max(D_{2T} - S_{2T}k_2, 0)\} = P_1 + P_2, \tag{11}$$

where, $E_{1,2}$ is the risk neutral expectations operator over S_1 and S_2. In other words, the aggregate RV premium for two banks is the sum of the individual bank RV premiums, P_1 and P_2. Note that this result holds, even if the two stocks are correlated. Implicitly, we have used the known property of the multivariate normal distribution, according to which the marginal distributions of a normal are also normal (Kotz et al., 2001). Thus, by "integrating out" one of the two variables we are left with the ith option, which, applied to our model is the RV premium for the ith bank, $i = 1, 2$.

In the limited coverage case with two banks, let us assume that both banks are subject to the same audit/repricing date. This assumption is necessary to make the model tractable. The aggregate value of insurance must also equal the sum of the individual insurance values for each bank but, instead of trying to compute these individual values, we pursue another approach. The combined insurance is given by the following:

$$\begin{aligned} p &= \mathrm{e}^{-rT} E_{1,2}\{\min(V_T, \max(D_{1T} - S_{1T}k_1, 0) + \max(D_{2T} - S_{2T}k_2, 0))\} \\ &= \mathrm{e}^{-rT} E_{1,2} \left\{ \begin{array}{cccc} D_{1T} - S_{1T}k_1 & S_{1T} < D_{1T}/k_1, & S_{2T} > D_{1T}/k_2, & V_T \geqslant D_{1T} - S_{1T}k_1 \\ V_T & S_{1T} < D_{1T}/k_1, & S_{2T} > D_{2T}/k_2, & V_T < D_{1T} - S_{1T}k \\ D_{2T} - S_{2T}k_2 & S_{1T} > D_{1T}/k_1, & S_{2T} < D_{2T}/k_2, & V_T \geqslant D_{2T} - S_{2T}k \\ V_T & S_{1T} > D_{1T}/k_1, & S_{2T} < D_{2T}/k_2, & V_T < D_{2T} - S_{2T}k \\ m & S_{1T} < D_{1T}/k_1, & S_{2T} < D_{2T}/k_2, & V_T \geqslant m \\ V_T & S_{1T} < D_{1T}/k_1, & S_{2T} < D_{2T}/k_2, & V_T < m \\ 0 & & \text{otherwise} & \end{array} \right\}, \end{aligned} \tag{12}$$

where

$$m = D_{1T} - S_{1T}k_1 + D_{2T} - S_{2T}k_2 \tag{13}$$

is the insurance payoff when both banks fail, while the fund is solvent, and k_i is the ratio of deposits to total liabilities for the ith bank.

The first line of Eq. (12) gives the value of the put option as the discounted expected insurance payoff function. This specific payoff function meets the aggregation property, that is, it equals the sum of the individual insurance payoffs, regardless of how the total payoff will be distributed among depositors of the two banks. The top first line in the large brackets of Eq. (12) shows the total insurance payoff in the case that only the first bank fails and the fund assets are sufficient to meet the insurance obligation. The second line shows the payoff when the first bank fails and the fund assets are insufficient. Similarly, the third and fourth lines are for the case in which the second bank fails. The fifth and sixth lines show the total payoff when both banks fail.

A difficulty with Eq. (12) is that we cannot "integrate out" along bank assets as we did in the case of no credit risk. Bank failure events are not statistically independent, because they are linked through the available fund reserves. Thus, we have to use the joint distribution of the bank assets. The value of the put is given by the following:

$$p=\frac{e^{-rT}}{\sigma_1\sigma_2 T}\left[\int_0^{\infty}\int_0^{\infty}\frac{\min(V_T,\max(D_{1T}-s_1k_1,0)+\max(D_{2T}-s_2k_2,0))}{s_1s_2}f_2\,\mathrm{d}s_1\,\mathrm{d}s_2\right], \tag{14}$$

where f_2 denotes the standard bivariate normal density under risk neutrality.

In principle, we can derive the implied insurance fund for any number of banks by extending Eqs. (11) and (14) and using Eq. (10) to solve for V. For exposition purposes, let us apply the technique for up to three ABHCs, assuming that the fund insures just the specified number of companies. The three hypothetical ABHCs would account for a combined 4.1% of the total domestic deposits among BIF-member commercial banks in 2000.

Fig. 2 displays the limited insurance as a function of the fund reserves and as a proportion of the full insurance. The latter is the aggregate RV premium and comes from extending Eq. (11). For a given level of coverage, the relative premium curve becomes less steep, and its curvature declines, as we increase the number of insured banks. This means that transforming the implicit insurance to explicit becomes more expensive at the margin, a fact that makes financial sense.

Panel A of Table 3 displays the full coverage insurance in basis points and million dollars. Panel B of the same Table gives the implied reserves for the three ABHCs, given coverage levels of 50%, 70%, 90% and 99%. Observe that the implied reserves appear to increase roughly linearly with the number of insured companies, if we hold α constant. Implied reserves also increase faster for higher levels of coverage than for lower levels. Repeating the computations for more companies, can give us better information about the evolution of implied reserves. Of course, based on Table 3 alone, we can make no projections for all FDIC insured banks, due to the small number of observations. However, it is apparent that some estimates of the actual BIF reserves are attainable. [2]

6. Concluding comments

This paper proposes a new methodology connecting premiums with the reserves of a bank guaranty fund, given a target coverage level. The model extends the related options literature on deposit insurance and contributes to the ongoing discussion about the capital adequacy of the BIF. No specific level for the BIF reserves

[2] Regarding computation, no problems worth mentioning were encountered during the numerical calculations for this paper using the *Mathematica* software. Root finding algorithms are now standard and very accurate and none was sensitive to initial conditions. To speed up numerical calculations, the options were computed at a limited number of fund levels, and the results were interpolated with third degree polynomials. The estimation error of the quasi Monte Carlo method used for multiple integrals is more related to the number of observations drawn than the integral dimension (Evans and Swartz, 2000). The only impediment is processing speed, which can be prohibitive for higher degree multiple integrals.

Table 3
Multiple banks: Insurance and implied reserves

Coverage level (%)	1 ABHC		2 ABHCs		3 ABHCs	
Panel A: Full insurance value (Aggregate RV premium. In basis points and million dollars)						
	2.5[a]	7.5[b]	2.5	14.9	2.5	22.4
Panel B: Implied reserves (in million dollars)						
99	3,045		3,957		4,897	
90	1,676		1,942		2,217	
70	925		1,030		1,130	
50	547		600		649	

[a] In basis points.
[b] In million dollars at end 2000. This is the aggregate RV premium. Estimates are for the specific number of Average Bank Holding Companies (ABHCs), and not for the whole sample or the banking system. Panel A numbers are not exact multiples of the one-ABHC case due to rounding.

is proposed, because that would depend on the coverage desired by policy makers and on the reference options model. A useful result for policy is that the values of explicit and implicit insurance are linked with the level of reserves. Therefore, the model could be employed as a component of a broader optimization function.

The new approach has certain advantages over actuarial approaches in determining guaranty fund reserves, because it does not require estimates of a loss distribution. This is a useful feature, especially in an environment of changing expected losses. Among the shortcomings of the model are its short-run focus and the inherited criticism attached to options models of insurance and debt pricing.

Acknowledgements

The author would like to thank the FDIC for providing the data on the BIF, P. Refenes, G. Skiadopoulos, E. Tsionas, D. Psychoyios, B. Houvardas and seminar participants at Athens University of Economics and Business for useful comments. Useful suggestions by two anonymous referees are especially acknowledged. Any remaining errors are the author's responsibility.

References

Anderson, R., Sundaresan, S., 2000. A comparative study of structural models of corporate bond yields: An exploratory investigation. Journal of Finance 24, 255–269.

Allen, L., Saunders, A., 1993. Forbearance and the valuation of deposit insurance as a callable put. Journal of Banking and Finance 17, 629–643.

Cummins, J.R., 1988. Risk based premiums for insurance guaranty funds. Journal of Finance 43, 823–839.

De Nicolo, G., Kwast, M., 2002. Systemic risk and financial consolidation: Are they related? Journal of Banking and Finance 26, 261–880.

Evans, M., Swartz, T., 2000. Approximating Integrals via Monte Carlo and Deterministic Methods. Oxford University Press, New York.

FDIC, 2001. Keeping the Promise: Recommendations for Deposit Insurance Reform. Washington, DC.
Hull, J., White, A., 1995. The impact of default risk on the prices of options and other derivative securities. Journal of Banking and Finance 19, 299–322.
Jarrow, R., Turnbull, S., 1995. Pricing derivatives on financial securities subject to credit risk. Journal of Finance 10, 53–85.
Jones, E.P., Mason, S., Rosenfeld, R., 1984. Contingent claims analysis of corporate capital structures: An empirical investigation. Journal of Finance 39, 611–625.
Johnson, H., Stulz, R., 1987. The pricing of options with default risk. Journal of Finance 42, 267–280.
Klein, P., 1996. Pricing Black–Scholes options with correlated credit risk. Journal of Banking and Finance 20, 1211–1229.
Klein, P., Inglis, M., 2001. Pricing vulnerable european options when the option's payoff can increase the risk of financial distress. Journal of Banking and Finance 25, 993–1012.
Kotz, S., Balakrishnan, N., Johnson, N., 2001. In: Continuous Multivariate Distributions, vol. 1. Wiley, New York.
Kuritzkes, A., Schuermann, T., Weiner, S., 2002. Deposit insurance and risk management in the U.S. banking system: How much? How safe? Who pays? Working Paper 02-02. Wharton Financial Institutions Center.
Marcus, A., Shaked, I., 1984. The valuation of FDIC deposit insurance using option-pricing estimates. Journal of Money, Credit and Banking 16, 446–460.
Merton, R., 1974. On the pricing of corporate debt: The risk structure of interest rates. Journal of Finance 29, 449–470.
Merton, R., 1977. An analytic derivation of the cost of deposit insurance and loan guarantees. Journal of Banking and Finance 1, 3–11.
Merton, R., 1978. On the cost of deposit insurance when there are surveillance costs. Journal of Business 51, 439–451.
Osterberg, W., 1996. The impact of depositor preference laws. Federal Reserve Bank of Clevaland Economic Review 32 (3), 2–11.
Pennacchi, G., 2000. The effects of setting deposit insurance premiums to target insurance fund reserves. Journal of Financial Services Research 17 (1), 153–180.
Pyle, D., 1986. Capital regulation and deposit insurance. Journal of Banking and Finance 10, 189–202.
Ronn, E., Verma, A., 1986. Pricing risk-adjusted deposit insurance: An options-based model. Journal of Finance 41, 871–895.
Sheehan, K., 1998. Capitalization of the bank insurance fund. Working Paper 98-01. FDIC.