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Panic, Liquidity and the Lender of Last Resort: A Strategic Analysis

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Abstract

This paper develops a model in which panics are caused by the strategic behavior of agents who temporarily monopolize the supply of privately controlled cash reserves. The decision to exercise this "monopoly power" results in localized "corners" on the money market and hence an abrupt alteration in the rate of exchange between cash and non-monetary assets. This sudden appearance of a premium on liquidity produces the dramatic increase in interest rates, decrease in security prices and wave of "contagious" bank runs which are characteristic of panics. Since the nonzero probability of a panic's occurrence reduces the expected rate of return on bank deposits, individuals respond to the threat of this outcome by hoarding otherwise productive resources. As this has the effect of reducing investment—and therefore output, consumption and government tax revenue—deposit insurance and an institutionalized of lender of last resort (which prevents panics by ensuring that the supply of legal tender is sufficiently elastic to guarantee competitive behavior among private holders of cash reserves) emerge endogenously as the result of utility maximizing behavior.

Panic, Liquidity and the Lender of Last Resort: A Strategic Analysis

R. Glen Donaldson[1]

1 Introduction and Summary

Jevons [1884] defines a panic as "...a rapid rise in the rate of discount, a sudden flood of bankruptcy, and a fall in consols [as well as stock prices], followed by a rise."[2] The purpose of this paper is to develop a model capable of explaining the causes of, and observed responses to, such panics. The method of analysis employed is essentially an extended "money market" version of Dunn and Spatt's [1984] strategic analysis of the market for sinking fund bonds. The central hypothesis of the current paper is that historically observed sudden movements in "panic variables" (such as interest rates, stock prices and intermediary failures, etc.) are the result of unusually large excess demands for legal tender, which create temporary local monopolies on the supply of privately held cash reserves. Given this hypothesis, historically observed public and private responses to panics are investigated as "optimal" reactions to a monopolized, or "cornered", money market. One of the paper's most interesting results is that, if the government's objective is to maximize expected output, consumption, utility and tax revenue, the optimal policy mix includes both deposit insurance and an elastic money supply controlled by a "corner breaking" Federal Reserve; the same combination of policies which has been in effect in the U.S.A. since 1934.

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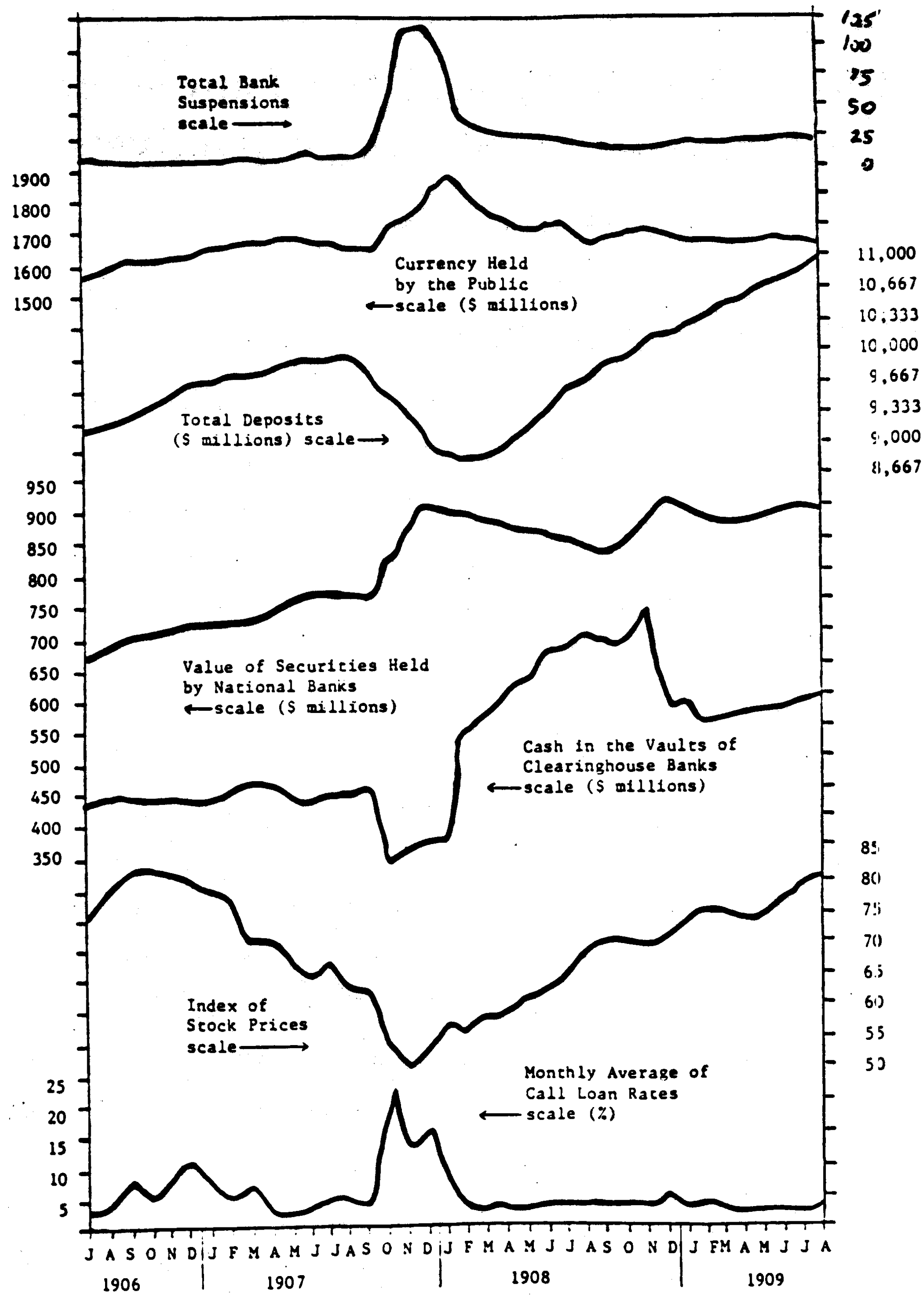
[2] Jevons [1884], p. 8.

Figure 1: Selected Statistics 1906–1909



DATA SOURCES: Monthly average of call loan rates on the New York Exchange: *Banking and Monetary Statistics*, p.440. Common stock index of the New York Exchange: *Ibid*, pp. 479-80. Cash in the vaults of New York Clearinghouse member-banks: *Monetary Statistics of the United States*, p. 380. Value of non-U.S. government securities owned by national banks: *A Study of the Cyclical Fluctuations occurring in the National Banking System During the Years 1903 to 1921*, p.67. Total deposits in all types of banks: *A Monetary History of the United States*, pp. 705–6. Currency held by the public: *Ibid*, pp. 705-6. Total bank suspensions: *Historical Statistics of the U.S.*, p.273, and *Commercial and Financial Chronicle*, various issues.

The specific types of behavior this paper attempts to explain are perhaps best summarized in a brief account of events that surrounded America's last pre-Fed panic: the "Knickerbocker panic" of 1907.[4] The data presented in Figure 1 reveal that the panic was preceded by a 26% decline in stock prices over the twelve month interval beginning September 1906. Newspaper reports of the day suggest that this development caused serious doubt to be cast on the solvency of several New York trust companies whose asset portfolios contained large stock-collateralized loans. This doubt manifested itself when, on the morning of October 22, 1907, Knickerbocker Trust (the third largest trust company in New York) was run as a result of depositor belief that the trust had made uncollectable loans to the failing Morse-Heinze-Thomas copper stock speculation syndicate. The panic of 1907 began that same afternoon when Knickerbocker was forced to suspend operations.

Figure 1 reveals that the ensuing wave of runs on other intermediaries (many of them trust companies) led to a decline in the number of deposits, an increase in the quantity of cash held by the public, and a dramatic rise in the number of suspensions. Protected by only a 5% cash reserve requirement (compared to a 25% cash reserve requirement for the city's national banks), New York's run trust companies were the first intermediaries to founder. In an effort to acquire the cash demanded of them by running depositors, the trusts called in many of their outstanding loans. The effect of this policy was twofold. First, the forced liquidation of the collateral that backed many of these loans depressed average stock prices by an additional 35% during the month of October alone. Second, in an effort to avoid selling their assets at severely depressed prices, demanders of cash at the New York Exchange bid call loan rates up to a high of 125% per annum (the October average was 21%) .[5]

The primary suppliers of cash to security markets and troubled intermediaries, during the panic, were what Sprague [1910] refers to as the nation's "ultimate reserve": New York's central reserve city clearinghouse national banks (the largest six of which con-

[4] This episode is of particular interest to the current study for two reasons. First, unlike earlier panics, the data from 1907 are relatively complete and reliable. Second, Friedman and Schwartz [1963], and others, have suggested that creation of the Federal Reserve as official lender of last resort was the government's ultimate response to the severity of 1907's panic.

[5] Andrew [1910], p.136.

trolled almost two thirds of New York's available national bank reserves, or roughly 40% of the economy's total vault cash).[6] These banks not only purchased the securities of cash demanding dealers and brokers at the Exchange[7], they also supplied money directly to fundamentally solvent, but temporarily illiquid, financial institutions. Both the Trust Company of America and Lincoln Trust, for example, were "bailed out" by sizable loans from clearinghouse national banks. The scope and severity of the financial crisis—which was largely attributed to the inelasticity of the American money supply—gave rise to Congress's creation of the National Monetary Commission and its 1908 passage of the Aldrich-Vreeland Act, both of which were designed to allow for the rapid expansion of the monetary base during times of panic.[8] The Aldrich-Vreeland Act, which allowed for such an expansion through the private printing and distribution of bank notes, was eventually replaced with a 1913 bill to establish the Federal Reserve as the government controlled lender of last resort.

In an effort to reproduce Table 1's statistical patterns and the type of behavior historically observed during—and in response to—panics, the remainder of this paper is organized as follows. Section 2 develops a simple model of a stylized economy in which the "central reserve city clearinghouse national banks" control the economy's cash reserves while "trust companies" possess demand deposits as liabilities and have claims to risky investment projects as assets. A run on a specific trust company occurs when depositors discover that the trust in question has made "bad" investments of sufficient magnitude to drive the value of its assets below that of its deposit liabilities. As was the case during the panic of 1907, run trust companies raise the legal tender withdrawing depositors demand of them

[6]Sprague [1910], p.234 and Hall [1924].

[7]On October 24, for example, a consortium of New York national banks supplied an extraordinary $19 million to demanders of cash on the floor of the Exchange at interest rates in the neighbourhood of 50% per annum. Source: Tallman [1984].

[8]Prior to 1908, emergency expansion of the American money supply was contingent upon the receipt of specie from abroad (most notably from the Bank of England) and on the domestic government's injection of excess legal tender reserves previously held by the U.S. treasury. The panic of 1907 was exacerbated by the fact that (i) the treasury had already been forced to release most of its legal tender during the "rich mans' panic" which occurred in the spring of 1907, and (ii) the bank of England had just passed a new law restricting the use of American "finance bills" to rapidly transfer gold claims between London and New York, thereby necessitating the time consuming and costly shipment of actual gold bullion across the Atlantic.

by selling their assets to, or borrowing cash from, the central reserve banks. Section 3.1 proves that, if there is perfect competition among the banks that bid for the securities sold by run trust companies, the equilibrium rate of return associated with purchasing such securities equals the (constant) opportunity cost of cash. The rate of return on cash reserves is therefore unaffected by the runs, and runs on the fundamentally insolvent trust companies do not spread to other sound intermediaries. Thus, while this section's results explain why, for example, over 1000 intermediaries failed during the ten year period prior to the panic of 1907 without causing radical movements in either interest rates or stock prices, it does not explain why interest rates suddenly rose, security prices suddenly fell, and previously sound intermediaries foundered during the panic itself. Section 3.2 therefore examines the possibility of strategic behavior by the suppliers of cash reserves. If trust companys' liquidity needs are unusually large (which would be the case if a universally "bad" investment shock caused a large number of trust companies to become insolvent, and therefore run), or if the economy's total stock of cash is concentrated in the vaults of but a few banks, some bank (say, bank i) may discover that the total demand for legal tender exceeds the combined reserves of all other banks. Bank i is therefore said to enjoy "monopoly power" over some portion of its cash reserves. The propositions and proofs of this section argue that bank i will maximize its profits by demanding a strategically determined "liquidity premium" on the portion of its cash reserves over which "monopoly power" can be exercised. The result is the decline in stock prices (i.e. the value of non-cash assets) and the increase in interest rates (i.e. the price of cash), characteristic of panics. This disturbance in the rate of exchange between monetary and non-monetary assets causes depositor runs, which were originally limited to fundamentally insolvent intermediaries, to become "contagious" and spread to other previously sound institutions which become suddenly "illiquid" as the premium on cash drives the liquidation value of their real assets below that of their dollar denominated deposit liabilities. Section 3.3 offers a numerical example of a cash monopoly-produced panic in an effort to examine the importance of the "liquidity premium" and "contagion" features of panics. This section's model-generated statistics mimic historically observed movements in interest rates, stock prices, numbers of intermediary failures, deposits and the quantity of cash held by the public. Moreover, the existence of a premium on liquidity accounts for Figure 1's movements in both vault cash *and* securities, as banks use their excess reserves to purchase underpriced securities from other agents with short positions in legal tender and long positions in non-monetary assets. In Section 4 it is demonstrated that a lender of last resort, such as the Federal Reserve, can prevent panics—and therefore increase savers' optimal deposit/storage ratio, investment, expected output, consumption, utility and tax revenue—by providing the money market with a flexible supply of legal tender sufficient to thwart any individual attempts to monopolize a portion of the money stock and create a premium on cash. Conclusions are contained in Section 5.

2 The Model

The purpose of this section is to define a simple static environment in which to study banking and financial panics. Unlike most bank run models in which there is only one commodity and no cash, there are two items in the current model: securities and cash. Cash (denominated in units called "dollars") is assumed to possess all the attributes of legal tender, while a security is a promise to pay the bearer one dollar. A security can therefore be thought of as either a $1 discount bond, or as a collection of stocks whose total value is $1 (each security could therefore represent two $.50 stocks or half of a $2 stock, etc). Hence, a fall in the equilibrium price of securities can represent both an increase in interest rates and/or a fall in stock prices.

In an effort to reconstruct the events of 1907, and panics in general, this section also defines four classes of utility or profit maximizing agents. Each agent, by virtue of its objective (or decision rule) and financial position, is a stylized representation of its historical counterpart as presented in the introduction to this paper. These agents are:

Trust Companies: Trust companies have demand deposits as liabilities and investments in various "projects" as assets. In an effort to account for the fact that the trusts of 1907 kept relatively small cash reserves (New York trust companies were subject to only a 5% cash reserve requirement, compared to a 25% cash reserve requirement for the city's national banks[9]) trusts in this model are assumed to possess no cash. When run, profit maximizing trust companies therefore raise the cash demanded of them by selling securities (each with a face value of $1) to the highest bidder. The cash so acquired is then distributed to depositors on a "first-come first-serve" sequential basis.

Passive Cash Holders: Passive cash holders are designed to represent agents such as foreign holders of legal tender (e.g. the Bank of England and its gold reserves) and domestic hoarders of cash. It is therefore assumed that these stylized agents possess an unlimited supply of cash with which they will purchase all securities sold by trust companies should the rate of return from doing so rise above passive cash holders' constant opportunity cost rate.

Savers: Savers possess no liabilities and have demand deposits at trust companies as assets. Savers are assumed to operate under the utility maximizing decision rule that they will run any trust company whose assets' liquidation value is less than that of its liabilities. This action is motivated by each risk averse saver's fear that his failure to run an insolvent trust may result in the inability to withdraw his funds before the sequentially servicing institution exhausts its insufficient resources.

Banks: Although New York's national bank's did, like trust companies, issue demand deposits, their primary role in the panic of 1907 (and, indeed, in most pre-Fed panics) was the suppliers of liquidity (recall, from the introduction, that New York's six largest national banks alone possessed roughly 40% of the economy's total supply of vault cash at the beginning of 1907's panic). In order to capture this feature of the central reserve city banks, the stylized banks in this model are assumed to possess no deposit liabilities and control the entire supply of mobilizable cash (i.e. all cash not controlled by passive cash holders). Each of the $i = 1 \ldots m$ banks therefore maximizes its profits by selecting the number of securities it should attempt to purchase and the price that should be bid for each security offered for sale by run trust companies.

[9] Myers [1931], p.220 and p. 252.

It will be proven below that there are two possible environments in which a bank can purchase securities: one in which some banks possess monopoly power over a portion of their cash holdings, and one in which every bank behaves like a perfect competitor when supplying cash to security selling trust companies. In order to formally specify these environments, define C_j and C_T as:

C_j: the quantity of cash possessed by bank j.

C_T: the total quantity of cash demanded by all run trusts.

Definition 1 *Bank i's* **monopoly power** *in cash, Q_i, is defined to be the greater of the total quantity of cash demanded by all run trust companies minus the sum of all other banks' supply of cash, and zero.*

$$Q_i = max(C_T - \sum_{j \neq i}^{m} C_j,\ 0)$$

Definition 2 *A* **market corner** *exists if $0 < Q_i$ for at least one i (i.e. at least one bank has monopoly power).*

Definition 3 *A* **perfect market corner** *exists if $Q_i = C_T$ for some i (i.e. one bank controls all the economy's cash)*[10] .[11]

Given its stated objectives, and the preceding definitions, each bank's profit maximizing decision can be formalized as equation (1),

[10]Since it is unlikely that any bank has, or will ever, control 100% of the economy's mobilizable cash, the body of this paper does not deal with the case of a perfect corner. Refinements to the following propositions and proofs required to account for a perfect corner, however, are included in the appendix since they may be important in the application of this paper's results to other problems.

[11]In order to clarify the concepts introduced in definitions 1 through 3, consider a modified cash version of Dunn and Spatt's [1984] example of a corner on the market for sinking fund bonds. Suppose $C_T = 75$ (run trusts demand a total of $75) and banks' combined reserves of $100 are distributed among the $i = 1 \ldots m$ institutions according to the following vector.

$$C = [C_1, C_2, C_3, C_4, ..., C_m] = [55, 35, 10, 0, ..., 0]$$

$$Max_{(R_i^k, R_i^{nk}, C_i^k, C_i^{nk})} \Pi_i = C_i^k(R_i^k - 1) + C_i^{nk}(R_i^{nk} - 1) \tag{1}$$

whose variables are:

R_i^k: the rate of return banker i demands on a security purchased with cash over which he possesses monopoly power (i.e. the inverse of the price paid for the security, $R = 1/P$),

R_i^{nk}: the rate of return banker i demands on each security purchased with cash over which he possesses no monopoly (or "corner") power,

C_i^k: the quantity of cash banker i spends on securities purchased with reserves over which he possesses monopoly power.

C_i^{nk}: the quantity of cash banker i spends on securities purchased with legal tender reserves over which he possesses no monopoly power.

and each bank's opportunity cost of cash has been normalized to 1.

One final definition is required before the equilibrium values of R_i^k, R_i^{nk}, C_i^k and C_i^{nk}

Each bank's monopoly power, as given by definition 1, is therefore:

$$\begin{aligned}
C_T - \textstyle\sum_{j=2}^{m} C_j &= 75 - (35 + 10) &= 30 &\quad \rightarrow Q_1 = 30 \\
C_T - \textstyle\sum_{j\neq 1,\neq 3}^{m} C_j &= 75 - (55 + 10) &= 10 &\quad \rightarrow Q_2 = 10 \\
C_T - \textstyle\sum_{j\neq 1,\neq 2}^{m} C_j &= 75 - (55 + 35) &= -15 &\quad \rightarrow Q_3 = 0 \\
C_T - \textstyle\sum_{j\neq 1,2,3}^{m} C_j &= 75 - (55 + 35 + 10) &= -25 &\quad \rightarrow Q_i = 0 \quad \text{for } i = 4, \dots, m
\end{aligned}$$

Since $Q_i > 0$ for bankers 1 and 2, definition 2 reveals that, for the given value of C_T, the chosen distribution of cash among banks results in a money market corner. In this environment, bankers 4 through m are clearly unable to bid for the securities offerred for sale by run trust companies since these banks cannot supply any of the demanded cash. Banker 3, on the other hand, possesses some cash and is therefore able to bid for securities. Banker 3's monopoly power, however, is zero as his reserves are not required to satisfy the liquidity demands of security selling trust companies. Although banker 2 holds \$35, definition 1 states that he possesses monopoly power over only \$10 as bankers 1 and 3 can jointly satisfy all but \$10 worth of trust companies' liquidity requirement. Likewise, while banker 1 holds \$55, he possesses monopoly power over only \$30 as bankers 2 and 3 can, together, supply \$45 worth of the required \$75. Total monopoly power ($\sum_{i=1}^{m} Q_i$) is therefore 40. Alternatively, if $C_1 = 100$ and $C_i = 0\ \forall i \neq 1$, definition 3 states that banker 1 would possess perfect monopoly power over all of the demanded cash (i.e. $Q_1 = C_T = 75$). Conversely, if $C_i = 10; i = 1, 2, \dots 10$ and $C_i = 0\ \forall i > 10$, no banker would possess monopoly power (i.e. $Q_i = 0\ \forall i$) so no market corner would exist.

can be calculated. Suppose that 100% of the economy's trust companies were run and therefore compelled to sell securities in an effort to raise the cash demanded of them by their withdrawing depositors. This final definition (whose usefulness will soon become apparent) gives the unique rate of return such that, when banks demand this rate of return on the trust company securities they purchase with cash over which monopoly power can be exercised (as given in definition 1), trust companies are forced to sell 100% of their collective supply of securities and—in an effort to purchase all of these securities—each bank is required to spend 100% of its "cornered cash" (i.e. $Q_i \ \forall i$). If banks demanded a rate of return that was lower than this critical value, banks would exhaust the collective supply of cash over which they possess monopoly power, while the security selling trust companies would be able to raise 100% of the cash demanded of them by running depositors without having to liquidate 100% of their assets. If banks demanded a rate of return on securities purchased with cornered cash that was higher than that given by equation (2), trust companies would exhaust their supply of securities before banks had exhausted their supply of cornered cash. Thus,

Definition 4 *R^x is the unique security/cornered cash* **mutual exhaustion rate of return** *(i.e. one plus the mutual exhaustion interest rate)* .[12]

$$R^x = 1 + \frac{S^x - C_T}{\sum_{i=1}^{m} Q_i^x} \tag{2}$$

Equation (2)'s previously undefined variables are:

S^x: the total number of \$1 securities all of the economy's trust companies can potentially issue, based on the actual payoffs on their investment portfolios, $S^x > C_T$.

Q_i^x: the monopoly power bank i would possess if 100% of the economy's trust companies were run and they demanded a total of C_T dollars.

[12]Continuing the example begun in the previous footnote, suppose that the *ex post* rates of return on trust company investments are such that trusts can issue a combined total of 95 one-dollar securities. Given that $C_T = 75$ and $\sum_{i=1}^{m} Q_i = 40$, the mutual exhaustion rate of return in this example would be $R^x = 1 + (S^x - C_T)/\sum_{i=1}^{m} Q_i = 1 + (95 - 75)/40 = 1.5$. In this case of a perfect corner, when $\sum_{i=1}^{m} Q_i = 75$, the mutual exhaustion rate of return would be $R^x = 1 + (95 - 75)/75 = 1.27$.

3 Equilibrium Conditions

Given an initial distribution of cash among banks and the rate of return on each trust company's asset portfolio, an equilibrium in this model is specified by a vector containing the rate of return associated with each security purchased—or the inverse of the price at which each security is acquired—and the quantity of cash spent by each purchaser of securities (in other words, the equilibrium values of R^{nk}, R^k, C^{nk} and C^k from equation (1)). The number of securities sold may also be obtained as the product of the rate of return and cash spent.

3.1 The Competitive Solution

Define R^d and R_i^* as:

R^d: the rate of return trust companies promise savers on their deposits.

R_i^*: the underlying, or "fundamental", rate of return on trust company i's asset portfolio ($E\{R_i^*\} \geq R^d$).

Suppose that the liabilities of all trust companies for whom $R_i^* < R^d$ (i.e. the fundamentally insolvent trusts) are small enough, or that the supply of cash is distributed among banks evenly enough, so that no bank possesses monopoly power (i.e. $Q_i = 0 \; \forall i$). Since no market corner exists, the first term in equation (1) disappears and banks are left to choose R_i^{nk} and C_i^{nk} to maximize $\Pi_i = C_i^{nk}(R_i^{nk} - 1)$. Since, in a competitive environment with constant opportunity costs, each bank must make zero profit, the rate of return demanded on each security purchased with cash over which no monopoly power can be exercized, R^{nk}, must equal 1; the rate of return to storing cash. Hence, $R_i^{nk} = 1 \; \forall i$ (or the competitive price of each one-dollar security is \$1 and the competitive interest rate is zero). Given that the competitive rate of return on each security is 1, the shadow liquidation rate of return on each trust company's asset portfolio is equal to its actual payoff rate, R_i^*. Thus, since savers only run trust companies whose assets' liquidation value is less than that of their liabilities, *only* fundamentally insolvent trust companies (i.e those for whom $R_i^* < R^d$) are run in the absence of a corner on the market for cash.

Given that the money market clears at the equilibrium rate of return $R^{nk} = 1$, the supply of securities must also equal the demand for securities at the price of $\$1/R^{nk} = \$1$ per security. Hence, recalling that C_T is the total quantity of cash demanded by all run trusts and C_i^{nk} is the quantity of cash bank $i = 1, ..., m$ spends on securities purchased at the competitive price of \$1, it must be true that $\sum_{i=1}^{m} C_i^{nk} = C_T$. Thus, the competitive (i.e. no corner) equilibrium can be represented by the vector Ψ^{nk},

$$\Psi^{nk} = [R^{nk}, \sum_{i=1}^{m} C_i^{nk}] = [1, C_T]$$

which contains the competitive rate of return on securities purchased by banks and the total quantity of cash obtained by trusts. The total quantity of securities sold by trust companies in the absence of a cash corner is therefore $R_i^{nk} \sum_{i=1}^{m} C_i^{nk} = C_T$. Thus, in the absence of a corner, the quantity of cash acquired by trust companies equals the number of securities purchased by banks.

3.2 The Nash Solution in the Presence of a Market Corner

In the previous section, a market corner did not exist because no single banker's cash reserves were indispensable in the supply of liquidity to demanders of legal tender. This section considers the opposing case in which either the initial demand for cash is so large (which would occur if the realization of each trust's random rate of return on investment was such that many trust companies were fundamentally insolvent, and therefore run), or the supply of cash is so highly concentrated in the vaults of but a few banks, that some bank possesses monopoly power over a portion of his cash holdings (i.e. $Q_i > 0$ for some i). Definition 2 states that, in such a case, a "market corner" would be in operation. From Section 3.1, we know that a banker makes zero profit on the portion of the cash he uses to purchase securities at the competitive price of \$1. The second half of equation (1) can therefore be deleted and bank i's objective becomes $max_{(R_i^k, C_i^k)} \Pi_i = C_i^k(R_i^k - 1)$. Define the rate of return above which passive cash holders enter the market and purchase all securities offerred for sale by run trust companies as,

R^p: passive cash holders' opportunity cost rate of return ($R^p > 1$).

The equilibrium values of R_i^k and C_i^k are then given in propositions 1 and 2, respectively.

Proposition 1 *In the presence of a corner on the market for cash, each bank sets the demanded rate of return on securities purchased under corner conditions, R_i^k, equal to the minimum of R^x, the mutual exhaustion rate of return, and R^p, the rate above which passive cash holders will enter the market for securities.*

$$R_i^k = min[R^x, R^p]$$

Proof:[13] The proof of this proposition proceeds in two stages. First, suppose $R^p < R^x$. If banker i demands a lower rate of return than R^p on the cash over which he possesses monopoly power, he will not be maximizing profits, as he can lower his offer price further (i.e raise R_i^k) without facing any additional competition. Thus, if $R^p < R^x$, R_i^k must be greater than or equal to R^p. If banker i offers a lower price for securities than P^p (i.e. demands a higher rate of return than R^p), however, he will be undercut by passive cash holders who swarm into the market as soon as rates of return rise above R^p. Thus, when $R^p < R^x$, R_i^k must also be less than or equal to R^p. This gives the result that if $R^p < R^x$, then $R_i^k = R^p$. Second, consider the situation in which $R^x < R^p$. Suppose the banker sets $R_i^k < R^x$. In this case, he will not be maximizing profits as he can raise his demanded rate of return (lower his offer price) and therefore increase profits without losing any of his market share. Thus, if $R^x < R^p$, R_i^k must be greater than or equal to R^x. Suppose banker i set his demanded rate of return above the mutual exhaustion rate. Then, by definition 4 and equation (2), the total supply of trust company securities would be exhausted before all of the bank's "cornered" cash reserves would be exhausted. One of the bidding banks could therefore increase its profits by raising its offer price (i.e. lowering R_i^k) by some tiny amount and capturing that entire portion of the market. Thus, $R_i^k \leq R^x$. Hence, if

[13] Rates of return and prices will be used interchangeably in the proofs of the following propositions, subject to $R = 1/P$.

$R^x < R^p$, $R_i^k = R^x$. We therefore have the result that $R_i^k = min[R^x, R^p]$ for all $i = 1...m$ banks. **Q.E.D.**

Proposition 2 *The quantity of cash bank i spends on securities purchased at the corner price is equal to the quantity of monopoly power possessed by bank i.* $C_i^k = Q_i$ *for all i.*

Proof: Banker i cannot set $C_i^k > Q_i$ because any dollars he attempts to spend on securities purchase at the corner price $1/R^k$, in addition to those over which he has monopoly power, as given in definition 1, will be subject to competition from other bankers offering the higher competitive price. C_i^k can therefore be no greater than Q_i. Banker i will not set $C_i^k < Q_i$, however, as this choice will not maximize bank profits as given in equation (1). C_i^k must therefore be at least as great as Q_i. Thus, since $C_i^k \leq Q_i$ and $C_i^k \geq Q_i$, we have the desired result that $C_i^k = Q_i$. **Q.E.D.**

Since, by the proof of propositions 1 and 2, banks spend a total of $\sum_{i=1}^{m} Q_i$ dollars on securities purchased at the corner price of $1/R^k$, market clearing requires banks to spend a total of $C_T - \sum_{i=1}^{m} Q_i$ dollars (where C_T is the total quantity of cash demanded by run trusts) on securities purchased at the competitive price of \$1. The corner equilibrium can therefore be represented by the vector Ψ^k,

$$\Psi^k = [R^k, \sum_{i=1}^{m} C^k, R^{nk}, \sum_{i=1}^{m} C^{nk}] = [min(R^x,\ R^p),\ \sum_{i=1}^{m} Q_i,\ 1\ ,\ C_T - \sum_{i=1}^{m} Q_i]$$

which contains the corner rate of return, the quantity of cash spent on securities purchased at the corner price, the rate of return on securities purchased at the non-corner (i.e. competitive) price, and the total quantity of cash spent on non-cornered purchases. Hence, $R^k \sum_{i=1}^{m} C^k = (min[R^x, R^p])(\sum_{i=1}^{m} Q_i)$ securities are purchased at the corner price of $\$1/R^k = \$1/min[R^x, R^p]$, and $R^{nk} \sum_{i=1}^{m} C^{nk} = C_T - \sum_{i=1}^{m} Q_i$ securities are purchased at the competitive price of $\$1/R^{nk} = \$1$.

At the end of section 3.1 it was noted that, in the absence of a corner, the shadow liquidation rate of return on a trust's asset portfolio equalled its actual rate of return, R_i^*. Thus, since savers only ran trust companies whose asset liquidation rate of return is less than the rate promised to savers on deposits, only fundamentally insolvent trusts (i.e. those for whom $R_i^* < R^d$, where R^d is the rate of return trusts promise savers on their deposits) were run in the competitive environment. In a cornered market, however, the liquidation rate of return on a trust's asset portfolio is $R_i^*/R^k < R_i^*$, since the corner price of a \$1 security is only $\$1/R^k < \$1$. Thus, during a cash-corner, fundamentally solvent—but temporarily illiquid—trust companies (i.e. those for whom $R^d \leq R_i^*$ but $R_i^*/R^k < R^d$) are now run *in addition* to the fundamentally insolvent trusts (i.e. those for whom $R^d > R_i^*$). This finding may explain the sudden increase in bank run activity, sometimes referred to the "contagion feature" of panics, which often signals the beginning of a banking or financial crisis. Furthermore, since $R^k > 1$, interest rates are higher and stock prices are lower (since $P = 1/R$) in the corner environment than they were in the non-corner (i.e. non-panic) environment. This result is consistent with Jevon's definition of a panic quoted in the introduction to this paper. Finally, unlike current bank run models, the preceeding analysis accounts for both the historically observed flow of cash out of bank vaults *and* the flow of securities toward the controllers of significant long positions in legal tender (e.g. New York's central reserve city clearinghouse national banks) during panics.[14]

3.3 An Example

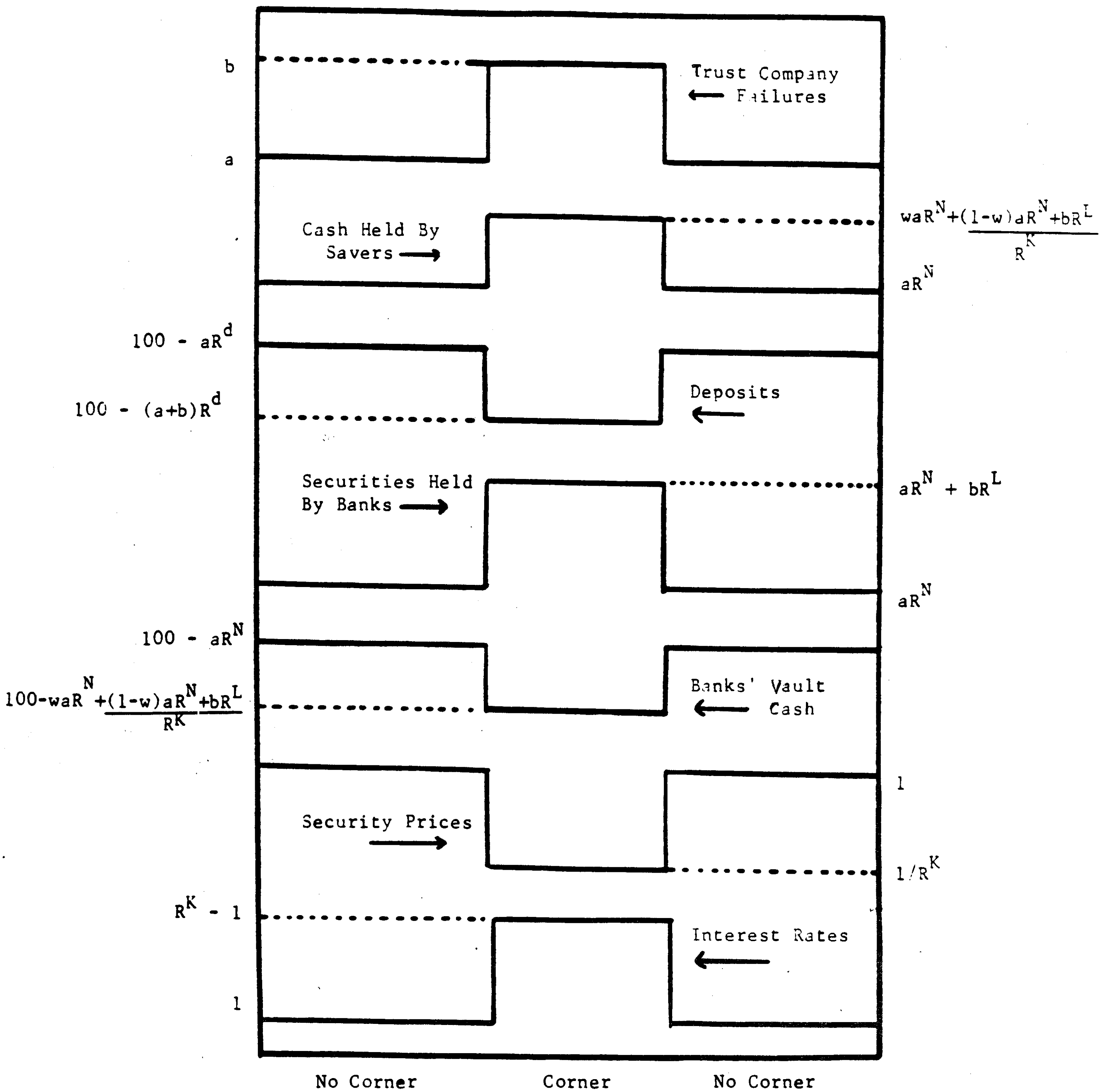
Suppose there are three trust companies which—in the interest of comparison to the historical account of the panic of 1907, contained in the introduction to this paper—are named Knickerbocker Trust (whose failure signalled the beginning of 1907's panic), Lincoln Trust (which was subsequently run and had its assets purchased by New York's national banks), and Guarantee Trust (which was not run during the panic of 1907). Recalling that R^d is the

[14] An extension of this model, provided in Donaldson [1988], also accounts for the observation that reserve banks often colluded to combine their reserve positions during panics. The essence of this papers' argument can be extrapolated from an embellishment of the example in footnote 11, whose logical extension reveals that collusion among cash-holding banks has the potential to increase monopoly power and therefore profits.

rate of return promised to depositors and R^k is the rate of return demanded by suppliers of cash over which corner power may be exercised, let the realized rates of return on each of the three trusts' asset portfolios be R^N $(R^N < R^d)$, R^L $(R^L/R^k < R^d < R^L)$, and R^G $(R^G/R^k > R^d)$ respectively. In the absence of a corner, when the equilibrium interest rate is $[R^{nk} - 1] = 0$ and the selling price of a \$1 security is $1/R^{nk} = 1$, Knickerbocker would be run, since $R^K < R^d$, while Lincoln and Guarantee would not be run, since $R^L > R^d$ and $R^G > R^d$. Assuming Knickerbocker possess a% of saver's deposits, the values of seven model generated statistics in the absence of a market corner can be summarized as the first and third columns of Figure 2 (in which all entries are in percentage terms). These entries reveal that banks purchase aR^N securities for an equal amount of dollars and trusts are left with a total of $R^d(1-a)$ deposit liabilities. Savers hold aR^N dollars, in aggregate, although some of the savers will hold $\$R^d$ while those who found themselves at the back of Knickerbocker's running queue will not have been able to withdraw any funds.

The center column of Figure 2 summarizes the values of the same seven variables in the event of a market corner, during which the equilibrium corner interest rate is $(R^k - 1) > 0$ and the corner price of securities is $1/R^k < 1$. Since $R^L/R^k < R^d$, the corner-caused premium on liquidity allows the initial run on Knickerbocker Trust to become "contagious" and spread to the fundamentally solvent—but now temporarily illiquid—Lincoln Trust, which is assumed to possess $[b-a]$% of savers' deposits. Banks therefore purchase w percent $(0 < w < 100)$ of Knickerbocker's portfolio at the competitive price of \$1 and the remainder at the corner price of $\$1/R^k$. Since Lincoln is only run during a corner, all of its assets are purchased at the corner price. As a result of the runs on Knickerbocker and Lincoln, aggregate deposit liabilities fall to $100 - (a+b)R^d$. As a result of the "liquidity premium" which exists during the market corner, banks are able to purchase $aR^N + bR^L$ securities with only $waR^N + [(1-w)aR^N + bR^L]/R^k$ dollars worth of vault cash (which, once banks purchase the securities from trusts and trusts release the cash so acquired to running depositors, becomes "cash held by savers").

Figure 2: Selected Model–Generated Statistics



It is interesting to note that the existence of a corner on the market for legal tender, which sends security prices tumbling downward, interest rates shooting upward and forces a run on the otherwise healthy Lincoln trust, allows the banks who purchase Lincoln's undervalued assets to capture not only the trust's operating profit $(R^L - R^d)$, but savers' profits $(R^d - 1)$ and a portion of savers' capital $(1 - R^L/R^k)$ as well.[15] This means that although banks (at least the stylized ones in this model) make zero profits most of the time, when they do make profits these profits are much greater than those realized by trust companies in a non-panic environment. This may help to explain why, under the national banking system, the central reserve city banks were willing to place such a large portion of their asset portfolios in nonearning cash reserves (the cash reserve requirements for central reserve city national banks was 25%, in 1907, compared to 12.5% for nonreserve national banks and only 5% for trust companies[16]).

Perhaps the most important result of this example is that the contents of Figure 2 appear to be quite similar to the historical data from the panic of 1907 contained in Figure 1. This observation could be viewed as at least preliminary evidence in support of the argument that the panic of 1907, and perhaps other panics, may have been the result of corners on the market for cash.

4 The Lender of Last Resort

Given Section 3's results concerning the causes of panics, the source of various statistical fluctuations and the motivation for historically observed "panic behavior", this paper now considers the manner in which the possibility of a panic's occurrence might affect individual

[15]One might argue that running savers should, themselves, accept securities (at par) in lieu of cash. As in real life, however, this may not occur because depositors may not be certain of the true value of a particular trust's assets. Banks, on the other hand, have access to such information. J.P. Morgan's well documented bailout of Lincoln Trust during the panic of 1907, for example, occurred only after he had personally reviewed the trust's balance sheet; an opportunity not generally available to running depositors. One may then use this example to further argue that banks profit, during a panic, because of their superior information and not because of their corner power. Note, however, that while all banks have access to the same information, only the banks with corner power actually profit by it (the same was true in 1907 when Lincoln's books were opened before the entire clearinghouse association, but it was still the cash-rich J.P. Morgan and Company which provided Lincoln Trust with the necessary funds).

[16]Myers [1931], p. 220 and p. 252.

deposit decisions and government policy. Suppose that, within the context of our model, each saver maximizes his or her expected utility by selecting the fraction of wealth to be deposited in risky intermediaries and the fraction to be stored. In other words, saver j choose φ^j to maximize equation (3).

$$Max_{\{\varphi^j\}} \quad E\{U^j([1-\varphi^j] + \varphi^j \sum_{i=1}^{n} \alpha_i^j D_i^j [R_i^*; Q(C), R^k(R^p)])\} \tag{3}$$

in which the previously undefined variables are:

$E\{U^j(\cdot)\}$: saver j's expected utility function with a relative risk aversion parameter no greater than unity,

φ^j: the fraction of cash saver j places on deposit in various financial intermediaries.

α_i^j: the fraction of saver j's total deposits which are placed in trust company i ($i = 1...n$),

D_i^j: the realized rate of return on a saver j's deposits in trust i,

Q: the total quantity of all banks' monopoly power (i.e $Q = \sum_{j=1}^{m} Q_j$),

C: the total quantity of cash possessed by all banks (i.e. $C = \sum_{j=1}^{m} C_j$),

and the expected rate of return on storage is unity.

When selecting their optimal ratio of deposits to storage, rational savers will account for the possibility that the corner/panic equilibrium might obtain instead of the desired competitive outcome. As the probability of a corner rises, expected returns from holding risky deposits fall, relative to returns from storage, due to the increased probability of a panic and the associated increase in the probability of intermediary failure as the result of a run. As the risk adjusted relative expected rate of return on deposits declines, so too will individuals' optimal ratio of deposits to storage. Moreover, since (at least in this model) financial intermediaries facilitate investment, expected output, consumption and utility will also fall as investment decreases and storage increases in response to the decrease in deposits (i.e. panics—or fears of panic—have real effects).[17] This assertion, the form of

[17] Indeed, Figure 1 reveals that storage (currency held by the public) rose from \$1.6 billion, in Sept. 1907, to \$1.9 billion in Jan., 1908 and returned to \$1.7 billion by Sept., 1908., while risky deposits (total bank

equation (3) and the results of the previous section suggest the following proposition; the proof of which is presented in the appendix.

Proposition 3 *The fraction of wealth each saver deposits in risky trust companies, φ^j, (and therefore investment, expected output, consumption and utility) is nondecreasing in the total quantity of cash held by banks, C, and is nonincreasing in R^p, the constant upper bound on the "corner" rate of return.*

Given the preceding proposition, it can be argued that a government interested in increasing expected output, expected consumption, savers' expected utility and—given a constant tax rate—even its own expected revenue, can achieve its objective by adopting a number policies designed to increase savers' "optimal" deposit/storage ratio over the level of φ^j that would be "optimaly" chosen in an environment in which corner-produced panics are possible. The proof of proposition 3 reveals that one way to increase φ^j is to "elasticize" the money supply, C, by allowing banks to print additional dollars, backed by securities, during times of financial crisis. This was the solution enacted by passage of the Aldrich-Vreeland Act of 1908, which allowed for the backing of new bank notes with commercial paper during times of financial emergency. By allowing banks to issue security-backed dollars during panics, banks with little or no cash would be able to enter the market for securities sold by run trust companies. As soon as the originally cash-rich banks cornered the money market and began to demand a premium on the cash over which they possessed monopoly power—thereby driving interest rates up, security prices down and previously solvent intermediaries into bankruptcy—all banks (no matter if the distribution of cash was originally skewed in their favor or not) would enter security markets and, through competitive bidding with newly created cash, drive interest rates and security prices back to their pre-run levels, break the market corner and stop the panic. The Aldrich-Vreeland

deposits) went from \$9.9 billion to \$9.0 billion and then returned to \$9.9 billion over the same period. As for the panic's real effects, investment went from \$148 million in the third quarter of 1907 to \$106 million in the first quarter of 1908, to \$173 in the third quarter of 1908. Output, over the same period went, from \$218 million to \$110 million to \$130 million. Source: Figure 1 and *Historical Statistics of the U.S.*, p.342 and pp. A262-3.

policy therefore prevents panics by reducing each bank's monopoly power to a level at which no market corner (and thus no panic) can occur .[18]

According to Proposition 3's proof, a second policy that would also prevent runs on fundamentally insolvent intermediaries from becoming "contagious" and spreading to other institutions, is the Federal Reserve policy. This policy states that the government itself, through the Fed's discount window, will purchase the assets of (or provide loans to) failing financial intermediaries. By making this promise, the government effectively becomes another passive cash holder ready to enter the market for securities as soon as the rate of return associated with purchasing such assets rise above R_G^p. The government can enforce the no-corner competitive solution, and savers' concomitant choice of an increased deposit/storage ratio, by setting $R_G^p = 1$; thereby removing the incentive for banks with monopoly power to demand a premium on their cornered cash (to see this, reconsider proposition 1 after setting $R^p = R_G^p = 1$). Thus, while the Aldrich-Vreeland policy ensures the competitive outcome by controlling banks' monopoly power (i.e. ensuring that it is zero) the Federal Reserve policy prevents panics by removing the incentive for cash-holding agents to exploit this power. Note, however, that while both policies produce the same result the Federal Reserve policy may be prefered by the government for at least two reasons. A first (unmodeled) reason is that the Fed policy gives the government greater regulatory control over the issuence of legal tender. The second reason is that adoption of the Fed policy allows the government to become an active, and potentially profitable, player in the market for undervalued securities in the event of an attempted market corner.[19] These observations may provide at least a partial explanation for the

[18] Indeed, the banking sector's power to rapidly expand the money supply under the provisions of the Aldrich-Vreeland Act has been generally credited with greatly reducing the severity and duration of the panic which erupted at the outbreak of World War I.

[19] Although Proposition 1 implies that, in equilibrium, no securities are sold to passive cash holders—which, if the Fed policy was in operation, would include the government and its agencies—some securities may actually be sold to the passive agents if the movement to equilibrium is not instantaneous. That foreign cash holders stand to profit from their position in the presence of market friction is evidenced by the fact that gold flows to and from the U.S. jumped from a fairly stable inflow of 20% to 40% of NNP in 1905-1907 to an average inflow of 68% of NNP in 1908 and then to an outflow of 83% in 1909 and 79% in 1910, after which flows were almost neutral in 1911 and 1912. The fact that domestic hoarders can profit during panics is evidenced by the observation that a "currency premium" existed during many episodes of panic. At the height of 1907's panic, for example, dealers and brokers on the New York Exchange were purchasing cash

government's decision to replace the Aldrich-Vreeland Act of 1908 with the Federal Reserve Act of 1913.

While both of the previous policies are effective in preventing runs on fundamentally insolvent intermediaries from becoming "contagious" and spreading to otherwise solvent institutions, neither one will prevent the failure of fundamentally insolvent trusts (which may include a significant [e.g. 1933-sized] portion of the economy's intermediaries, given a "bad" enough realization of the random investment shock R^*). Thus, since—even with an active Federal Reserve—intermediary failure is still possible, risk averse savers will still economize on their deposits; although not to the same extent as was the case prior to creation of the Fed. Hence, given that this model's economy-wide expected rate of return on investment, $E\{R^*\}$, is greater than 1 (the expected rate of return to storage), a government interested in further increasing investment, expected output, consumption and tax revenue may wish to also institute some type of deposit insurance in an effort to prevent *all* runs, remove all intermediary risk and therefore increase deposits. Note, however, that if this deposit insurance is to be incomplete (i.e. a $100,000 limit per depositor), the insurance policy must be offered in conjunction with a policy designed to prevent money market corners since monopoly power can still potentially be exercised over the stock of cash demanded by intermediaries who are responsible for the uninsured portion of their withdrawn deposits. It may therefore be optimal for the government to create both a Federal Reserve system *and* deposit insurance in an effort to prevent panics, increase output and maximize consumption, utility and tax revenue; the same combination of policies which has been in effect, in the U.S.A, since 1934.[20]

from "shopkeepers and men on the street" at rates in excess of 4% (e.g. a $104 cheque drawn on a "safe" clearinghouse bank would be exchanged for $100 cash. For more on this, see Sprague [1910] and Kindleberger [1978]).

[20] It is interesting to note that while complete insurance (i.e. $R^{insured} = R^d$) maximizes savers' utility, a government which funds its insurance expenditures with taxes can maximize its own revenues by setting $R^{insured} = 1 < R^d$ and offering lender of last resort services. This is because, in an insured environment, savers' opportunity cost of a riskless deposit is storage with a guaranteed rate of return equal to $1 < R^d$. Savers will therefore place all their funds in insured deposits (and therefore produce the revenue maximizing government's goal of complete investment at the minimum potential insurance cost) as soon as savers' certain rate of return from doing so reaches 1; the rate of return associated with hoarding. Along with other authors' findings that incomplete insurance may be required because of various informational problems, the preceding argument may to help explain the government's chosen policy mix of incomplete insurance and the Fed.

5 Conclusions

This paper has utilized a "money market" version of Dunn and Spatt's [1984] strategic analysis of the market for sinking fund bonds in an effort to reproduce historically observed "panic" behavior and data such as that presented this paper's introduction. The results of this exercise suggest that a panic may be characterized by the following chain of events. First, the process is initiated by some event (such as realization of a random technology shock; R_i^* in this paper) which creates an *initially* limited desire for liquidity. This event, alone, would normally be insufficient to cause a panic as the resulting demand for cash would normally be answered by an ample supply of legal tender offered at competitive prices. A second event, which is therefore necessary for bank runs to become "contagious" and produce a panic in the preceding model, is a corner on the market for cash. As the market corner is put into effect by the strategic response of agents who possess "monopoly power" over some portion of their cash reserves, the dollar value of securities is driven below its competitive level. Financial intermediaries with short positions in cash and long positions in non-monetary assets (such as stock-secured loans) then discover that, although they were previously sound, the shadow liquidation value of their assets has suddenly fallen below that of their liabilities. This news precipitates the third important phase in a panic: "contagious" bank run activity. When this occurs, institutions experiencing runs are compelled to liquidate their assets at the unusually low prices dictated to them by those agents who possess monopoly power over some portion of their cash reserves. If this liquidation involves the calling in of stock-secured loans, security prices will fall even further with the forced sale of collateralized stock. Interest rates will also increase dramatically at this time as agents, whose short positions in cash are being called, attempt to borrow the funds required to satisfy their creditors rather than be forced to liquidate their assets at severely depressed prices. As stock prices continue to fall, additional previously sound intermediaries become suddenly illiquid and more and more institutions therefore find themselves being run. The panic spreads throughout the economy as the cycle of falling stock prices, bank runs, liquidations, rising interest rates, falling stock prices, and so forth, continues. The panic finally stabilizes when asset prices and interest rates reach their lower and upper bounds, respectively, as given by proposition 1 of this paper. Given that a panic begins when agents who possess monopoly power over some portion of their legal tender reserves demand a "liquidity premium" on cash, this paper has also demonstrated that "contagious" panics can be prevented—and expected output, consumption and utility increased—by removing the premium on liquidity. This can be accomplished by either preventing cash holding agents from acquiring this monopoly power, as did the Aldrich-Vreeland Act, or by removing the incentive to use this power, a function which the Federal Reserve now performs.

Appendix

Proof of proposition 3: The proof, which revolves around equation (3), proceeds in several steps, beginning with (3)'s innermost set of brackets and working out. First, the proof of proposition 1 reveals that $\partial R^k/\partial R^p \geq 0$ (i.e. that the equilibrium corner rate of return on securities is nondecreasing in passive cash holders' opportunity cost rate of return, R^k's constant upper bound). Second, by appealing to definitions 1 and 2, it can be immediately seen that (i) $\partial Q/\partial C \leq 0$ (i.e. that total monopoly power is nonincreasing in total bank cash) and that (ii) by increasing C to the point where $Q = 0$, $R^k > 1$ will be replaced by $R^{nk} = 1$ as the relevant liquidation rate of return on securities.

Now that we have investigated the means by which R^k might be reduced, the third step is to demonstrate that such a reduction will result in an improving first order stochastically dominating shift in the distribution of each of equation (3)'s random variables $D_i^j(R_i^*; R^k)$, $\forall i$. To see this, consider the behavior of D_i^j over the range of R_i^*, given specific values of R^k. If $R_i^*/R^k < R^d$, trust company i is run run and each withdrawing saver receives R^d dollars until the trust exhausts its resources and declares bankruptcy; after which each saver who has not yet withdrawn receives zero. In this case, the average *ex post* rate of return to depositors at that trust company would be R^d multiplied the ratio of the trust's asset liquidation rate of return to the rate of return on its liabilities, or $R^d(R_i^*/R^k)/R^d = R^*/R^k$. Conversely, if $R_i^*/R^k \geq R^d$, trust i is not run and the realized rate of return on each saver's deposit would be R^d. D_i, the average realized rate of return on deposits in trust i, is therefore given by equation (4).

$$D_i = \begin{cases} R_i^*/R^k & ; R_i^*/R^k < R^d \\ R^d & ; R_i^*/R^k \geq R^d \end{cases} \tag{4}$$

From (4), it can be immediately seen that a decrease in R^k causes a shift in the distribution of D_i so that the new distribution is larger than the old distribution in the sense of first order stochastic dominance, as defined in Hadar and Russel [1971] (i.e decreasing R^k causes the value of D_i to weakly increase for any realization of R_i^*). Since the distribution of D_i is improved by a decrease in R^k, it must also be the case that a decline in the corner rate of return weakly improves the distribution of D_i^j, since each of trust company i's depositors will be able to withdraw at least as much cash as before if the trust company's asset liquidation value is increased. Finally, since the decline in R^k improves the distribution of D_i^j $\forall i$, it must weakly improve the distribution of $D^j = \sum_{i=1}^n \alpha_i^j D_i^j$.

The final step is to show that a first order stochastically dominating shift in D^j causes an increase in the optimal choice of saver j's φ. Since second order conditions are satisfied by the assumption of risk aversion, the necessary and sufficient condition for φ to be a maximum of equation (3) is given in equation (5) (the superscript j has been ommitted for simplicity)

$$E\{U'([1-\varphi]+\varphi D)(D-1)\} = E\{\Upsilon'\varphi)\ \} = 0 \tag{5}$$

Consider two choices of R^k which produce F and G: two cumulative distributions of $D(R^*)$, where F is greater than G in the sense of first order stochastic dominance (i.e $F[D(R^*)] \leq G[D(R^*)]\ \forall\ R^*$). Mirman [1971] demonstrated that a sufficient condition for $\varphi^F \geq \varphi^G$ (where φ^G is the value of φ savers optimally choose given the distribution G) is $\partial\Upsilon'/\partial D \geq 0$. Differentiating (5), inside expectations, with respect to D produces equation (6).

$$\partial\Upsilon'/\partial D = \varphi U''(\cdot)(D-1) + U'(\cdot) \tag{6}$$

The assumption that the measure of savers' relative risk aversion is no greater than unity can be formalized as equation (7), which can be rewritten as (8).

$$-[(D-1)\varphi+1]U''(\cdot)/U'(\cdot) \geq 1 \tag{7}$$

$$\varphi U''(\cdot)(D-1) + U'(\cdot) + U''(\cdot) \geq 0 \tag{8}$$

Since, by assumption, $U'' \leq 0$, and equation (8) is nonnegative, equation (6) is certainly nonnegative, which produces the desired result that $\varphi^F \geq \varphi^G$ since F is greater than G in the sense of first order stochastic dominance. Hence, $\partial\varphi/\partial R^k \leq 0$. Given the first three parts of this proof, this finding produces the desired results that $\partial\varphi/\partial C \geq 0$ and $\partial\varphi/\partial R^p \leq 0$, as given in the statement of proposition 3. **Q.E.D.**

Let $S^p \leq S^z$ be the total quantity of securities trust companies will be forced to sell when $R^k = R^p$ and $\sum_{i=1}^m Q_i = C_T$. Then,

Proposition 4 *In the case of a perfect corner on the market for cash,* $R^k = R^p$ (replaces proposition 1) *and* $\sum_{i=1}^m C_i^k = S^p/R^p$ (replaces proposition 2).

Proof: Since one banker (say banker i) is in control of a perfect corner, definition 1 states that he faces no active competition for his cash. If there were no passive cash holders, banker i would therefore set the demanded rate of return on securities arbitrarily close to infinity. Thus, assuming $R^p < \infty$, $R^k = R^p$ by the logic of the proof to proposition 1. Profit maximization implies that banker i will spend the minimum amount of cash necessary to acquire the entire supply of securities offered for sale by trusts for whom $R^*/R^p < R^d$. Therefore, since $C_{j\neq i} = 0$, $Q_i^k = C_i^k = \sum_{i=1}^m C_i^k = S^p/R^p$.**QED**

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