Optimal Cash Management for Investment Funds

by

Hayne Leland and Gregory Connor

March 1995
Optimal Cash Management for Investment Funds

Hayne Leland and Gregory Connor

Haas School of Business
University of California, Berkeley
and
BARRA International

March 1995

Finance Working Paper #244
ABSTRACT

We consider the question of how much cash should be held by an investment fund for transactions purposes. Cash is needed to meet redemptions and rights offerings; it is generated by dividends and contributions. It is assumed the cumulative cash flow follows a random walk, perhaps with a drift. If transactions costs were zero, it would be optimal to keep zero cash balances, since cash reduces expected return and adds to tracking error. But keeping cash balances at zero would be very expensive in the presence of transactions costs, since random walks have infinite variation.

The optimal cash policy requires a "no trade" interval [0, L*]. If cash balances are within this interval, no transfers between cash and portfolio securities takes place. If cash falls beneath zero, securities should be sold to return the cash balance to zero. If cash exceeds L*, cash should be invested in the portfolio to reduce the cash balance to L*.

We derive closed form solutions for L*, and show how this responds to changes in transactions costs and other parameters of cash flows and portfolio returns. Finally, a closed form estimate of expected turnover associated with optimal strategies is derived.
OPTIMAL CASH MANAGEMENT FOR INVESTMENT FUNDS

1. Introduction and Summary

Many institutional portfolio managers face the following problem. They have a benchmark or target portfolio which they wish to mimic or exceed. Typically this portfolio has little or no cash. But due to random cash flows in and out of the portfolio, managers must have some cash available. If trading costs were zero, the optimal "inventory" of cash would be zero: cash would immediately be put into the target portfolio when received; cash would instantly be raised by security sales when needed.

But if trading is costly, and cumulative cash flows follow a random walk (perhaps with drift), maintaining a continuously zero inventory of cash would be very expensive. The frequent small adjustments would, over time, require a very large amount of trading. On the other hand, maintaining a large cash inventory would create tracking error with respect to the benchmark and a lower expected return from investment.

We use a dynamic programming approach to determine the optimal cash inventory, when the investor has a long time horizon. We focus on the case of trading costs which are proportional to the volume of securities sold. First, we show that the nature of the optimal policy will involve no purchase or sale of securities as long as the cash inventory remains within a fixed interval. If the cash on hand ever falls beneath zero, securities will then be sold to bring the inventory back to zero: negative cash positions are not permitted. If cash inventory builds up, no compensating adjustments are made until the cash position exceeds an amount $L$. At that point, securities are bought, but only in amounts which reduce the cash position back to $L$. We call the interval $[0,L]$ of cash holdings the "no trade" zone.
The paper derives a closed-form solution for the optimal \( L = L^* \), and therefore the "no trade" interval. We show how the size of this interval depends on

- the costs of trading portfolio securities
- the risk and return of the target portfolio
- the drift and variance of random cash flows in and out of the fund
- the relative importance of tracking accuracy vs. trading costs.

Finally, we show how to predict the expected turnover (cash-to-securities and securities-to-cash transactions) which results from following the optimal cash management policy.

2. Formulation of the Problem

Let the target portfolio have expected rate of return \( \mu_p \) and variance \( \sigma_p \) per time unit. We assume there is no cash in this target portfolio. Let \( k \) represent the proportional trading costs (e.g. \( k = .01 \), if one-way trading costs are 1%). For simplicity we assume that all securities in the target portfolio are bought or sold proportionately, so that the composition of the securities portfolio (and its risk characteristics) remains constant.

Let \( w_t \) be the proportion of the fund (per unit) held in cash at time \( t \). Cash will randomly be generated or required as a result of dividends, rights offerings, net withdrawals, etc. Let \( \delta_t \) denote this random cash flow per unit, which is normally and independently distributed through time with constant mean \( \mu_\delta \) and variance \( \sigma_\delta \) per period.\(^1\) The increase or decrease in cash position resulting from sales or purchases of the underlying portfolio at time \( t \) will be denoted \( D_t \). It follows that the total change per unit in cash position between

\(^1\) In the limit of continuous time, we assume that cumulative cash flows \( C \) follow a random walk, with increments \( \delta = dC = \mu_\delta dt + \sigma_\delta dZ \), where \( Z \) is a standard Brownian motion. Thus \( \mathbb{E}(\delta) = \mu dt \) and \( \mathbb{E}(\delta^2) = \sigma^2 dt \).
periods is given by \( w_{t+1} - w_t = \delta_t + D_t \). Trading costs in period \( t \) will be \( k|D_t| \).

For related problems, it is well known that the optimal transactions strategy is to specify an interval over which no rebalancing between cash and the underlying portfolio takes place.\(^2\) This interval is bounded below by 0, indicating that the fund cannot maintain a negative cash position. If, because of random cash outflows, the cash position becomes negative, sufficient sales of securities must be undertaken to return the cash position to zero.\(^3\) \( L \) represents the upper bound of this no-action interval. If because of random cash inflows the cash position exceeds \( L \), cash will be invested in the target portfolio to reduce the cash position to \( L \). (It will be shown later that \( L \) does not depend upon \( t \)).

Given \( w_t \) and the above policy, the sequence of future cash positions per unit \( \{w_{t+1}, \ldots\} \) will be uniquely determined by the random cash flows \( \{\delta_{t+1}, \ldots\} \). If \( w_t \in [0,L] \), then

\[
\begin{align*}
w_{t+1} &= w_t + \delta_t. \\
\text{If } w_t + \delta_t < 0, \text{ then } w_{t+1} &= 0 \text{ (and } D_t = -(w_t + \delta_t)).
\end{align*}
\]

If \( w_t + \delta_t > L \), then \( w_{t+1} = L \) (and \( D_t = (L - w_t - \delta_t) \)).

Let \( V(w_t, 0, L) \) be the expected discounted cost over an infinite horizon, when the period \( t \) begins with cash fraction \( w_t \), and the no-action interval is \([0,L]\). (For simplicity, we shall henceforth suppress "0" as an argument of \( V \). \( V \) depends upon three cost factors: the expected future transactions costs; the expected return loss due to cash holding; and the total future variance of the tracking error (relative to the benchmark portfolio) resulting from the cash holding \( w \) weighted by a monetizing parameter \( \lambda \). The more important the accuracy of tracking the target, the larger will be \( \lambda \). The expected return loss over the period \((t, t+1)\) will equal \( \pi w_{t+1} \), where \( \pi \) is the risk premium (the difference between the

---

\(^2\) See, for example, Magill and Constantinides [1979], Constantinides [1986], Hodges and Neuberger [1989], and Dumas and Luciano [1991].

\(^3\) In the presence of fixed as well as proportional transactions costs, it will be optimal to return the cash position to a positive amount, rather than to zero. We discuss this case briefly in the Section 6.
expected return $\mu_p$ on the stock portfolio and the interest rate $r$ per period). The variance of tracking error will be $\sigma_p w_{t+1}^2$.

Finally, we allow for the possibility that the volatility reduction associated with the cash position over the period, $[(1 - (1-w_{t+1})^2)\sigma_p$, may provide an offsetting benefit, monetized by another parameter $\lambda$. Our base situation is when $\lambda > 0$ and $\lambda = 0$. However, we shall also consider the situation when $\lambda = 0$ and $\lambda > 0$. This latter formulation, while perhaps less realistic from the perspective of a money manager, is consistent with a "CAPM" formulation of investors who trade off risk and return.

We assume $V$ exists and is twice differentiable. $V(w_t, L)$ can be expressed as

$$V(w_t, L) = E \sum_{\tau=0}^{\infty} R^{-\tau}[k|D_1 + \pi w_{\tau+1} + \lambda w_{\tau+1}^2 \sigma_p - \lambda_1 [1 - (1-w_{\tau+1})^2] \sigma_p]$$

$R = 1/(I+r)$ is the discount rate, where $r$ is the rate of interest per unit time. $L$ affects the expected amount of trading and average size of $w_t$, and therefore affects $V$.

We may substitute for $D_1$ using the relationship $D_1 = w_{t+1} - w_t - \delta_t$. From recursive summation,

$$V(w_t, L) = E \sum_{\tau=0}^{\infty} R^{-\tau}[k|w_{t+1} - w_t - \delta_t + \pi w_{\tau+1} + \lambda w_{\tau+1}^2 \sigma_p - \lambda_1 [1 - (1-w_{\tau+1})^2] \sigma_p] + R[V(w_{t+1}, L)]$$

We may expand $V(w_{t+1}, L)$ in a Taylor Series expansion to get

---

4 We assume the following time sequencing. $w_t$ is the cash position entering period $t$. Immediately thereafter, $\delta_t$ is realized and $D_t$ is uniquely determined as previously described. Then $w_{t+1} = w_t + \delta_t + D_t$. The loss of expected return and tracking error are caused by $w_{t+1}$ over the period $(t, t+1]$. $w_{t+1}$ then is the cash position entering period $t+1$. 

4
(3) \[ V(w_t, L) = E\{k \mid w_{t+1} - w_t - \delta_t \mid \pi w_{t+1} + \lambda w_{t+1}^2 \sigma_p - \lambda_t [1-(I-w_{t+1})^2] \sigma_p + R[V(w_t, L) + V_w(w_t, L)(w_{t+1} - w_t) + .5V_{ww}(w_t, L)(w_{t+1} - w_t)^2] \} \]

where \( V_w(w_t, L) = \partial V(w_t, L)/\partial w_t \), etc. This can be rewritten as

(4) \[ V(w_t, L)(1 - R) = E\{k \mid w_{t+1} - w_t - \delta_t \mid \pi w_{t+1} + \lambda w_{t+1}^2 \sigma_p - \lambda_t [1-(I-w_{t+1})^2] \sigma_p + \mu \delta dt \}
+ \mu \delta dt \}

The continuous rate of interest, and \( 1 - R = 1 - e^{-rdt} = rdt - o(dt) \).

Finally, \( \sigma_p = \sigma \pi dt \) and \( \pi_t = \pi dt \).

Substituting these relationships into (4) and ignoring terms of \( o(dt) \) gives

\[ rV(w_t, L)dt = E\{w_{t+1} \pi dt + \lambda w_{t+1}^2 \sigma_p dt - \lambda_t [1-(I-w_{t+1})^2] \sigma_p dt + V_w(w_t, L) \mu \delta dt + .5V_{ww}(w_t, L) \sigma \delta dt \} \]

Since \( E[w_{t+1}] = w_t + \mu dt \), and \( E[w_{t+1}^2] = w_t^2 + O(dt) \), and these terms are multiplied by \( dt \), we have (ignoring terms of \( o(dt) \))

\[ rV(w_t, L)dt = w_t \pi dt + \lambda w_t^2 \sigma_p dt - \lambda_t [1-(I-w_t)^2] \sigma_p dt + V_w(w_t, L) \mu \delta dt + .5V_{ww}(w_t, L) \sigma \delta dt \]

Dividing by \( dt \) gives the fundamental differential equation for \( V(w_t, L) \) when \( w_t \in [0, L] \):

(5) \[ rV(w_t, L) = w_t \pi + \lambda w_t^2 \sigma_p - \lambda_t [1-(I-w_t)^2] \sigma_p + V_w(w_t, L) \mu \delta + .5V_{ww}(w_t, L) \sigma \delta \]

We henceforth omit the subscript "i" from \( w_p \) since the solution is time independent.

This in turn confirms that \( L \) will be independent of \( \tau \), as previously asserted.
3. Solution to the Problem

For given \( L \), the solution to the ordinary differential equation (5) is

\[
V(w, L) = C_1 e^{(\alpha - \zeta)w} + C_2 e^{(\alpha + \zeta)w} + a_1 w + a_2 w^2
\]

where

\[
z = \frac{(\mu_\delta^2 + 2r\sigma_\delta)^2}{\sigma_\delta} \quad \text{and} \quad x = \frac{\mu_\delta}{\sigma_\delta}
\]

and

\[
a_1 = \frac{(\lambda + \lambda_1)\sigma_p}{r^2} \left( \frac{2\mu_\delta^2}{r} + \sigma_\delta \right); \quad a_2 = \frac{2(\lambda + \lambda_1)\sigma_p\mu_\delta}{r^2} + \frac{(\pi - 2\lambda_1\sigma_\delta)}{r}; \quad a_3 = \frac{(\lambda + \lambda_1)\sigma_p}{r}
\]

For \( w > L \), \( V(w, L) = V(L, L) + k(w - L) \); for \( w < 0 \), \( V(w, L) = V(0, L) - kw \).

Boundary conditions, assuring "smooth pasting" at 0 and \( L \), are

(7i) \( V_w(0, L) = (x-z)C_1 + (x+z)C_2 + a_2 = -k \)

(7ii) \( V_w(L, L) = (x-z)C_1 e^{(x-\zeta)L} + (x+z)C_2 e^{(x+\zeta)L} + a_2 + 2a_3 L = k \)

where \( V_w(w, L) = \partial V(w, L)/\partial w \), \( V_L(w, L) = \partial V(w, L)/\partial L \), etc. Given \( L \), it is possible to solve for \( C_1 \) and \( C_2 \) from the above two equations. We denote these \( C_1(L) \) and \( C_2(L) \).
Differentiating (7i) and (7ii) with respect to $L$ yields

\[(8i) \quad V_{wL}(0,L) = (x-z)C_{1L} + (x+z)C_{2L} = 0\]

and

\[(8ii) \quad V_{wL}(L,L) = (x-z)^2 C_1 e^{(x-z)L} + (x+z)^2 C_2 e^{(x+z)L} + 2a_3 + (x-z)C_{1L} e^{(x-z)L} + (x+z)C_{2L} e^{(x+z)L} = 0\]

where $C_{LL} = \partial C_L / \partial L$, etc.

To find the optimal $L^*$, we minimize (6) with respect to $L$, at arbitrary $w \in [0,L]$. Since only $C_1$ and $C_2$ are functions of $L$, the first order condition is

\[(9) \quad V_L(w,L) = C_{1L} e^{(x-z)L} + C_{2L} e^{(x+z)L} = 0\]

When $w = 0$, equation (9) reduces to

\[(10) \quad C_{1L} + C_{2L} = 0\]

Now (8i) and (10) can hold simultaneously if and only if

\[(11) \quad C_{1L} = C_{2L} = 0\]

at $L = L^*$. But (11) implies equation (9) holds for all $w \in [0,L]$ at $L = L^*$. That is, the same $L^*$ minimizes expected costs for all $w \in [0,L^*]$, not simply at $w = 0$. Condition (11) also allows simplification of (8ii) at $L = L^*$:

\[(12) \quad V_{wL}(L,L) = (x-z)^2 C_1 e^{(x-z)L} + (x+z)^2 C_2 e^{(x+z)L} + 2a_3 = 0\]

Equations (7i), (7ii), and (12) can be solved for the three unknowns $C_1$, $C_2$, and $L = L^*$. 

4) An Example, with Comparative Statics

Consider an example where

\[ r = 0.10 \text{ (10\% annual riskfree rate)} \]
\[ \sigma_{\delta} = 0.01 \text{ (10\% standard deviation in annual cash flows)} \]
\[ \mu_{\delta} = 0 \text{ (no drift in annual cash flows)} \]
\[ \sigma_{\rho} = 0.04 \text{ (20\% standard deviation in returns of the stock portfolio)} \]
\[ k = 0.01 \text{ (1\% one-way transactions costs)} \]
\[ \pi = 0.10 \text{ (the expected return on the stock portfolio exceeds the return on cash by 10\%)} \]
\[ \lambda = 10; \; \lambda_1 = 0. \]

Solving the appropriate equations gives

\[ L^* = 0.04065 \]
\[ V(w, L^*) = 0.4 + w + 4w^2 - 0.0635 e^{4.472w} - 0.2894 e^{4.472w} \]

Figure 1 graphs \( V(w, L^*) \) as a function of \( w \). For \( w < 0 \), \( V(w, L^*) = V(0, L^*) - kw \).
For \( w > L^* \), \( V(w, L^*) = V(L^*, L^*) + k(w - L^*) \).

In our example, the correct strategy is not to adjust the cash position as long as it remains between 0\% and 4.065\% of portfolio value. If it falls beneath zero, enough securities should be sold to return it to zero. If it exceeds 4.065\%, enough securities should be sold to reduce the cash proportion to 4.065\%. The following will increase the maximum cash fraction \( L^* \):

- Higher transactions costs \( k \).
- Higher volatility of cash flow \( \sigma_{\delta} \).
- Lower expected cash flow \( \mu_{\delta} \).
> Lower volatility of the stock portfolio $\sigma_p$
> Lower risk premium $\pi$
> Lower tracking error weight $\lambda$

Consider the following separate parametric shifts and their effect on $L^*$ and $V(0, L^*)$, in comparison with the base case where $L^* = 0.04065$ and $V(0, L^*) = 0.04713$:

<table>
<thead>
<tr>
<th>Changed Parameter Value</th>
<th>Optimal $L^*$</th>
<th>$V(0, L^*)$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$k = 0.05$</td>
<td>0.0840</td>
<td>0.1110</td>
</tr>
<tr>
<td>$\sigma_\delta = 0.04$</td>
<td>0.0757</td>
<td>0.0983</td>
</tr>
<tr>
<td>$\mu_\delta = -0.05$</td>
<td>0.0434</td>
<td>0.0458</td>
</tr>
<tr>
<td>$\sigma_p = 0.0225$</td>
<td>0.0423</td>
<td>0.0461</td>
</tr>
<tr>
<td>$\pi = 0.06$</td>
<td>0.0485</td>
<td>0.0383</td>
</tr>
<tr>
<td>$\lambda = 5$</td>
<td>0.0565</td>
<td>0.0460</td>
</tr>
</tbody>
</table>

An "emerging markets" portfolio might have $k = 0.05$, $\sigma_p = 0.10$, $\sigma_\delta = 0.04$, $\mu_\delta = -0.05$, and $\pi = 0.20$. (We assume other parameters remain as in the base case). For this set of parameters, $L^* = 0.1127$ and $V(0, L^*) = 0.3257$. If $L$ were mistakenly chosen at the same level as the base case (.04065), then $V(0, 0.04065) = 0.5381$, implying an expected cost 67% above the optimal level.

We briefly consider the case where $\lambda = 0$ but $\lambda_1 > 0$. This is consistent with a mean-variance optimizer who recognizes that cash lowers expected return, but also risk. The investor has no additional penalty for tracking error. By assumption, the investor chooses $w = 0$ in the absence of transactions costs. That is,

$$0 = \arg\max_w \{\pi w - \lambda_1[(1-w)^2]\sigma_p\}$$

For this to be true

$$\lambda_1 = \pi/(2\sigma_p).$$
Given the other parameters of the base case, we find

\[ L^* = .147. \]

The maximal cash position in this situation is considerably greater than before. This is because there is not a separate penalty for "tracking error." Although \( w > 0 \) is suboptimal (when transactions costs are zero), increasing \( w \) from zero initially has only a small cost, since the fall in expected return is balanced by a fall in overall portfolio risk. Since transactions costs are the same here, the optimum occurs at a greater \( L \). Comparative statics, however, are similar in direction to the earlier case with \( \lambda > 0 \) and \( \lambda_1 = 0 \).

5. Expected Turnover of the Optimal Strategy

We have shown above how the interval \([0, L^*]\) is determined. But what are the expected trading costs and turnover of the optimal strategy? There is a "trick" that permits us to answer the question. Note that the differential equation (5) includes two terms associated with the cost of \( w > 0 \): the expected return loss \( \pi w \), plus the tracking error \( w^2 \) weighted by \( \lambda \).

The solution \( V(w, L) \) gives the total cost of the strategy: the expected trading costs, plus the costs associated with \( w > 0 \).

Now consider a special case of \( V(w, L) \), which we shall call \( T(w, L) \), when the terms associated with the cost of \( w > 0 \) are set equal to zero. This will represent the expected costs of trading alone.

The solution to (6) with the restrictions that \( \pi = 0 \), \( \lambda = 0 \) and \( \lambda_1 = 0 \) will generate \( T(w, L) \). The boundary conditions are also the same as (7i) and (7ii), with \( \pi = \lambda = \lambda_1 = 0 \). From (6), denoting the constants as \( K_1 \) and \( K_2 \) (to distinguish them from \( C_1 \) and \( C_2 \)):

\[ (13) \quad T(w, L) = K_2 e^{(x-z)w} + K_2 e^{(x+z)w}, \]
with boundary conditions

\[(I4^{'}) \quad (x-z)K_1 + (x+z)K_2 = -k \]

\[(I4^{'}) \quad (x-z)Ke^{(x-z)\mu} + (x+z)Ke^{(x+z)\mu} = k. \]

Given the \(L^*\) determined by the solution to the original problem, we can use these boundary conditions to solve for the constants \(K_1\) and \(K_2\) and therefore for the function \(T(w, L^*)\).

For the example considered in Section 4 above, with \(L = .04065\), we find

\[T(w, .04065) = .01345 e^{-4.672w} + .01122 e^{4.672w}. \]

\(T(w, L)\) represents total expected discounted transactions costs over the infinite time horizon.

When \(w = 0\), \(T(0, .04065) = .02467\). Annual transactions costs will simply be \(rT(w, L)\), and annual expected one-way turnover is \(rT(w, L)/k\). This is graphed in Figure 2, for the base case. Depending on the current level of \(w\), annual turnover is expected to be about 24.6%. It can be seen that turnover costs \(T(w, L)\) are slightly more than half the total costs \(V(w, L)\) in this case.

In contrast, the "emerging market" scenario described at the end of Section 4 incurs a cost \(T\) (when \(w = 0\)) of about 0.179, or .0179 annually. With transactions costs of 5%, this converts to an approximate annual turnover of about 35.9%. Note that although the variance of cash flows is much larger in comparison with the base case (\(\sigma_\delta = .04\) vs. .01), the turnover is less than proportionately greater, because the "no trade" interval is almost three times as great (\(L^* = .1127\) vs. .04065).
Figure 3 shows how turnover $T(0, L)$ depends upon $L$ for base case parameters. A good approximation for $T(0, L)$ is

$$(15) \quad T(0, L) = \sigma_\delta^2 m (0.5 + \frac{1}{e^m - 1})$$

where

$$m = \frac{(4 \mu_\delta^2 + 2r \sigma_\delta)^{1/2}}{\sigma_\delta}$$

This is an exact expression when $\mu_\delta = 0$, in which case $m = (2r/\sigma_\delta)^{1/2}$. The expected turnover for $w \in (0, L]$ will generally be different from the expected turnover when $w = 0$; however, the difference will be quite small when $L < 0.15$.

6. Extensions

The model is easily extended to a minimum cash boundary other than zero. For example, say the optimal portfolio has a 3% cash position. Then the cash position associated with the cash inventory fall to -3%, and still not require borrowing outside the fund. Such a change could readily be incorporated in the analysis via a change in boundary conditions, as could a requirement that cash balances (say) never be less than 2%, rather than 0.

The existence of a fixed transactions cost, in addition to a percentage transactions cost, would alter the nature of the optimal policy. Now two nested intervals must be described: $[0, L^*]$, in which no trading takes place, and $[L_1, L_2]$, the cash positions to which one trades when trading is triggered, with $0 < L_1 < L_2 < L^*$. The derivation of the optimal intervals remains for the future.

---

5 This is one-way (cash to securities or vice-versa) transactions. Often turnover is measured in "roundtrip" terms (securities to securities), in which case our turnover numbers would be divided by two.
7. Conclusions

We have derived precise answers for the optimal cash holding of an investment fund which has cumulative cash inflows and outflows described by a random walk (perhaps with a trend). By assumption, the fund desires cash only for transactions purposes. Cash may be generated by dividends and contributions, and may be demanded for rights offerings and redemptions. This cash would be instantly reinvested or created by sales of securities, were it not for transactions costs which would make such continuous reinvestment exceedingly costly.

The nature of the optimal cash policy is to allow cash to accumulate (or fall) randomly, with no selling or buying of securities, as long as the cash fraction is greater than or equal to zero, and less than or equal to an upper limit $L^*$. If the cash fraction falls beneath zero, securities must be sold in sufficient amount to return the cash position to zero. If the cash fraction exceeds $L^*$, the cash must be invested in securities such as to return the cash position to $L^*$.

A description of the optimal cash strategy therefore devolves into the determination of $L^*$. This paper has developed a set of equations whose solution determines $L^*$, and relates it to transactions costs, the mean and variance of random cash flow process, the riskiness of investment portfolio, and the investor's tradeoff between trading costs and tracking error. A simple extension of the analysis allows prediction of the turnover associated with the optimal strategy.
REFERENCES


Figure 1

Cost V

Cash Fraction
RESEARCH PROGRAM IN FINANCE AT THE
WALTER A. HAAS SCHOOL OF BUSINESS,
UNIVERSITY OF CALIFORNIA, BERKELEY

The Research Program in Finance in the Walter A. Haas School of Business at the University of California has as its purpose the conduct and encouragement of research in finance, investments, banking, securities markets, and financial institutions. The present reprint and working paper series were established in 1971 in conjunction with a grant from the Dean Witter Foundation.

INSTITUTE OF BUSINESS AND ECONOMIC RESEARCH
Carl Shapiro, Director

The Institute of Business and Economic Research is an organized research unit at the University of California, Berkeley, whose mission is to promote research by faculty and graduate students in the fields of business and economics. The Institute carries out its mission by organizing programs and activities that enrich the research environment, administering extramural research awards, publishing working papers, and making direct grants for research.