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THE PENSION INDUCEMENT TO RETIRE: AN OPTION VALUE ANALYSIS

James H. Stock

David A. Wise

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ABSTRACT

The option value model developed in an earlier paper is used to simulate the effect on retirement of changes in a firm's pension plan compared to the effect of changes in Social Security provisions. The provisions of the firm's pension plan have a much greater effect than Social Security regulations on the retirement decisions of the firm's employees. The analysis supports the following conclusions:

- Increasing the firm's early retirement age from 55 to 60, for example, would reduce by almost 40 percent, from .48 to .30, the fraction of employees that is retired by age 60.
- The effect of changes in Social Security rules, on the other hand, would be small. Raising the Social Security retirement ages by one year, for example, has very little effect on employee retirement rates. The proportion retired by age 62 is reduced by only about 4 percent.
- Changes in Social Security provisions that would otherwise encourage workers to continue working can easily be offset by countervailing changes in the provisions of the firm's pension plan. Firm responses, like delaying the Social Security offset to correspond to a later Social Security retirement age, may simply be a logical revision of current firm plan provisions.

James H. Stock
Harvard University
Kennedy School of Government
79 JFK Street
Cambridge, MA 02138

David A. Wise
National Bureau of Economic Research
1050 Massachusetts Avenue
Cambridge, MA 02138

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by

James H. Stock and David A. Wise

The labor force participation rates of older workers have declined dramatically in recent years. The data for men show the trend:

Year	Age 50-54	55-59	60-64	65+
1971	92.8	88.8	74.1	25.5
1986	88.9	79.0	54.9	17.5

A great deal of analysis has emphasized the role of Social Security provisions in encouraging earlier retirement. Recent examples are Blinder, Gordon and Wise [1980], Burkhauser [1980], Hurd and Boskin [1981], Gustman and Steinmeier [1986], Burtless and Moffitt [1984], Burtless [1986], Hausman and Wise [1985]. Several of these papers direct attention to the large increases in Social Security benefits in the early 1970s. These papers for the most part show only a modest effect of these increases on labor force participation rates; Hurd and Boskin [1984] is an exception.

Largely ignored have been firm pension plans. Firm pension plans were introduced rapidly beginning in the 1950s. Now about 50 percent of employees are covered by firm plans. The proportion of retiring workers that is covered by a firm pension is still rising rapidly. It increased from about 4 to 25 percent between 1950 and 1980 and is still rising rapidly. About 75 percent of covered employees have defined benefit plans. The benefit under such a plan is the promise by the employer to pay the worker a specified amount at retirement. The amount is typically determined by final salary and years of firm employment. Bulow [1981] described pension wealth accrual under these plans and Lazear [1983] emphasized the potential role of plan provisions in inducing early retirement, as a substitute for mandatory retirement. The very substantial incentive effects of these plans have been emphasized most recently by Kotlikoff and Wise [1985, 1987, 1988], who summarize the incentives of approximately 2500 plans covered by the Bureau of Labor Statistics Level of Benefits Survey, and consider in great detail the effects of the provisions of a large Fortune 500 firm. This work demonstrates that the typical firm plan provides a large reward for remaining with the firm until some age, often the early retirement age, and then a substantial inducement to leave the firm, often as early as 55. Almost all plans incorporate a large penalty for working past age 65. The gain in wage earnings from working an additional year is often offset in large part by a loss in the present value of future pension benefits.

There has been very little analysis of the actual effects of these incentives on retirement, however. Exceptions are Burkhauser [1979], Fields and Mitchell [1982], Lazear [1983], Kotlikoff and Wise [1987], and Hogarth [1988]. One reason for the limited attention has been the absence of appropriate data. The analysis in this paper is based on the personnel records of a large Fortune 500 firm. The firm pension plan was described in detail by Kotlikoff and Wise [1987], who also related the plan provisions to departure rates from the firm.

The goal of this paper is to quantify the effects of pension plan provisions on departure rates from the firm and, in particular, to demonstrate the effect of potential changes in plan provisions. A particularly important component of the analysis is to demonstrate the relative effects of changes in

Social Security versus firm pension plan provisions. The analysis is based on the "option value" model developed in Stock and Wise [1988].

The primary conclusions are that:

- Firm plans have a much greater effect than Social Security provisions on employee retirement decisions.
- Increasing the firm early retirement age from 55 to 60, for example, would reduce by almost 40 percent the proportion of employees who retire from the firm before age 60.
- The effect of changes in Social Security provisions that are intended to prolong the labor force participation of the elderly, like the planned increase in the retirement age, may be offset by the response of firms to the change.

We begin in section I with a description of the incentive effects faced by workers in the firm. The description of the incentive effects is also used to motivate our method of analysis. The option value model is summarized in section II. Parameter estimates are presented in section III and the model fit is emphasized. It is shown that the model captures extremely well the several discontinuous jumps in firm departure rates caused by pension plan and Social Security provisions. An out of sample test of the predictive validity of the model is also presented. Simulations of the effect on departure rates of changes in firm pension plan and in Social Security provisions are discussed in section IV. A summary and concluding discussion is in the last section.

I. The Firm Pension Plan and Retirement Incentives

The analysis in this paper is based on salesmen who are at least 50 years old and have been employed for at least three years.[1] To understand the

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[1]The criterion that they be employed three years facilitates the forecasting of future wage earnings on an individual basis. We plan in later work to consider other employee groups.

effect of the pension plan provisions, consider several figures. Figure 1 shows the expected future compensation of a person from our sample who is 50 years old and has been employed by the firm for 20 years.[2] It is important to consider total compensation--including wage earnings, the accrual of pension benefits, and the accrual of Social Security benefits. As compensation for working another year the employee receives salary earnings. He also receives compensation in the form of future pension benefits. The annual compensation in this form is the change in the present value of future pension benefits, due to working an additional year. This accrual is comparable to wage earnings. The accrual of Social Security benefits may also be calculated in a similar manner, and is also comparable to wage earnings. Figure 1 shows the present value at age 50 of expected future compensation in all three forms. The line labelled earnings represents cumulated earnings, by age of retirement.[3] For example, if the person were to retire at age 62, his cumulated earnings between age 50 and age 62, discounted to age 50 dollars would be about $300,000. The slope of the earnings line represents annual earnings discounted to age 50 dollars. Earnings decline rather slowly through age 60 and much more rapidly thereafter.

The solid line shows the accrual of firm pension plus Social Security benefits, again discounted to age 50 dollars. The shape of this profile is determined primarily by the pension plan provisions. The most important

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[2]For convenience, the graphs assume a 5 percent real discount rate and zero inflation. In the empirical model that is estimated, the discount rate is estimated and the inflation rate is assumed to be 5 percent.

[3]Departure from the firm would be a more accurate description than retirement, because for some employees the alternative to continued employment at the firm is likely to be another job, rather than retirement.

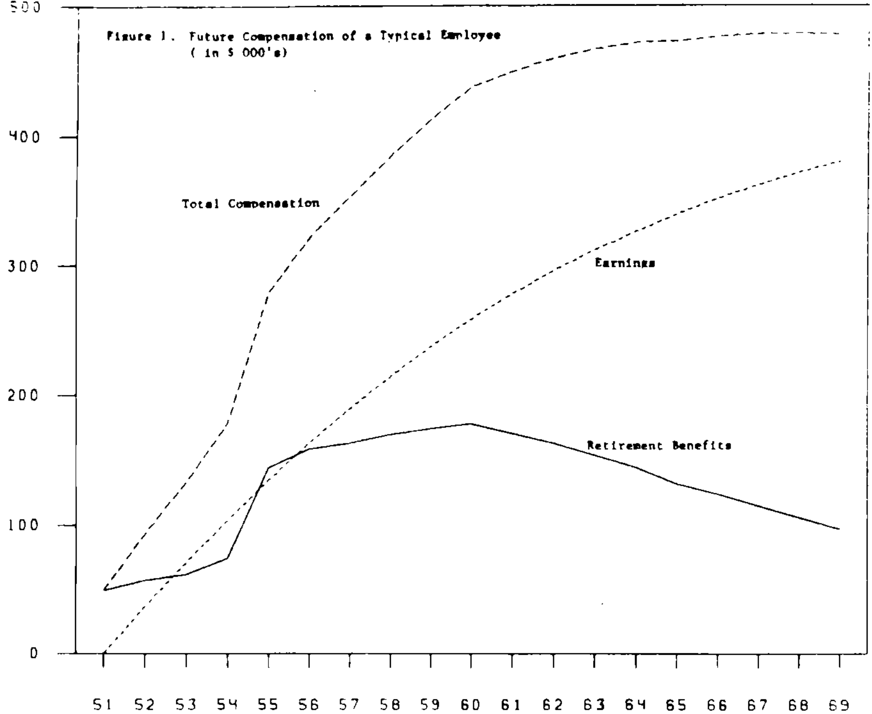


Figure 1. Future Compensation of a Typical Employee (in $ 000's)

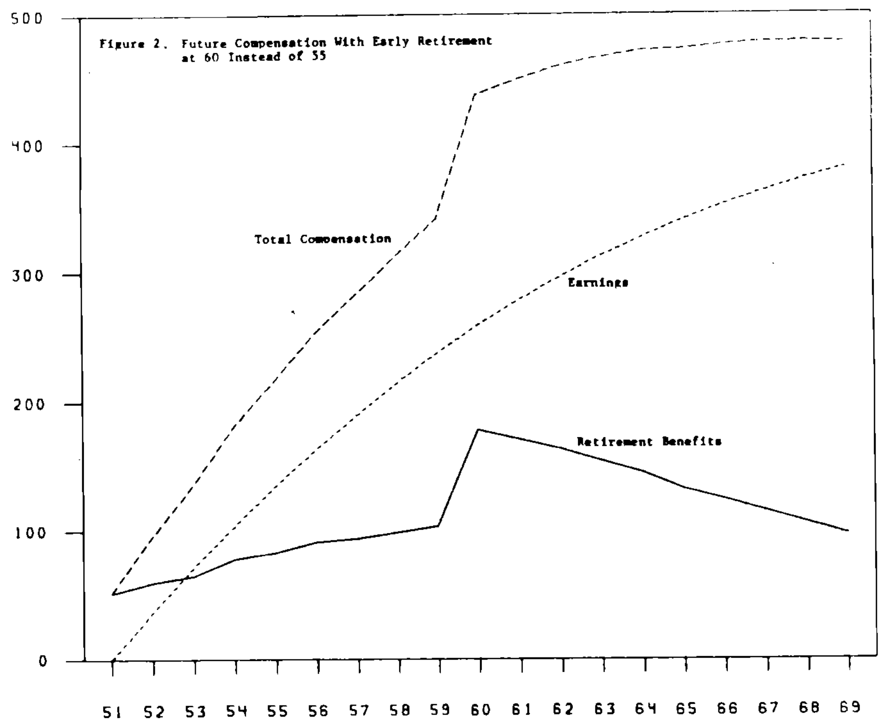
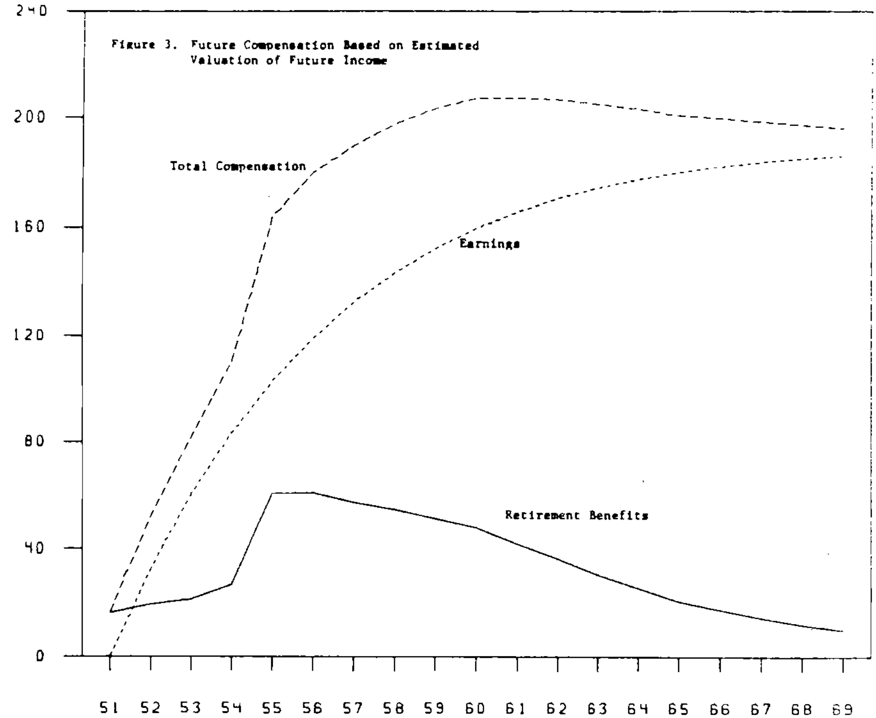


Figure 2. Future Compensation With Early Retirement at 60 Instead of 55


240
200
160
120
80
40
0
Figure 3. Future Compensation Based on Estimated Valuation of Future Income
Total Compensation
Earnings
Retirement Benefits
51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69

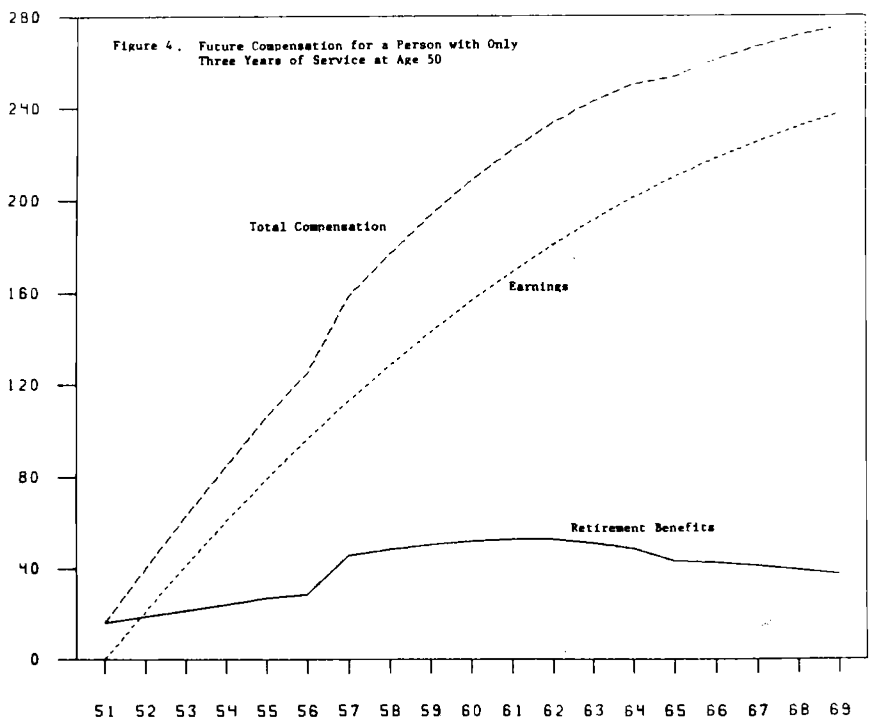

280
240
200
160
120
80
40
0
Figure 4. Future Compensation for a Person with Only Three Years of Service at Age 50
Total Compensation
Earnings
Retirement Benefits
51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69

Figure 5. Future Compensation From Age 58

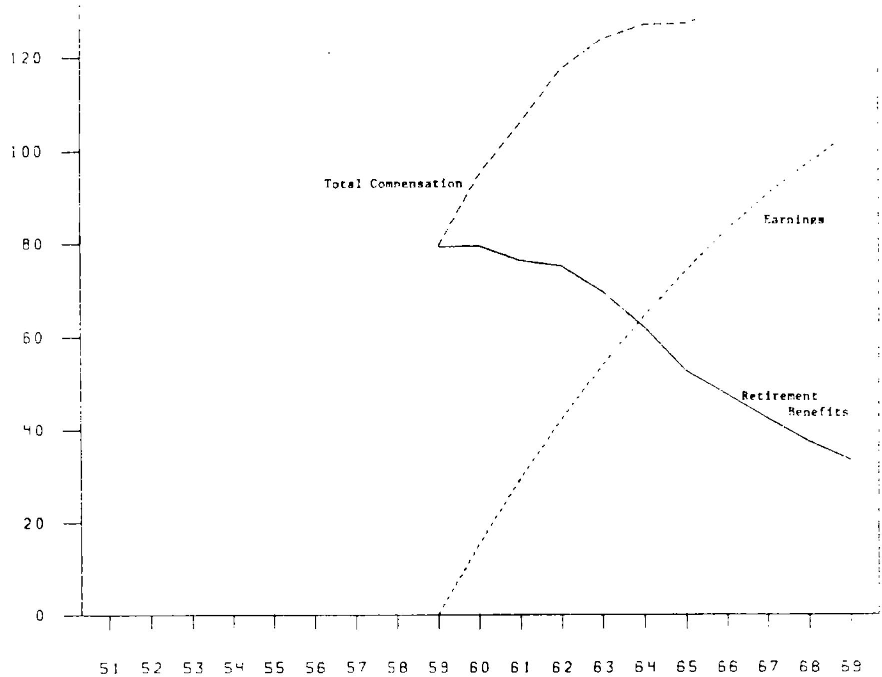
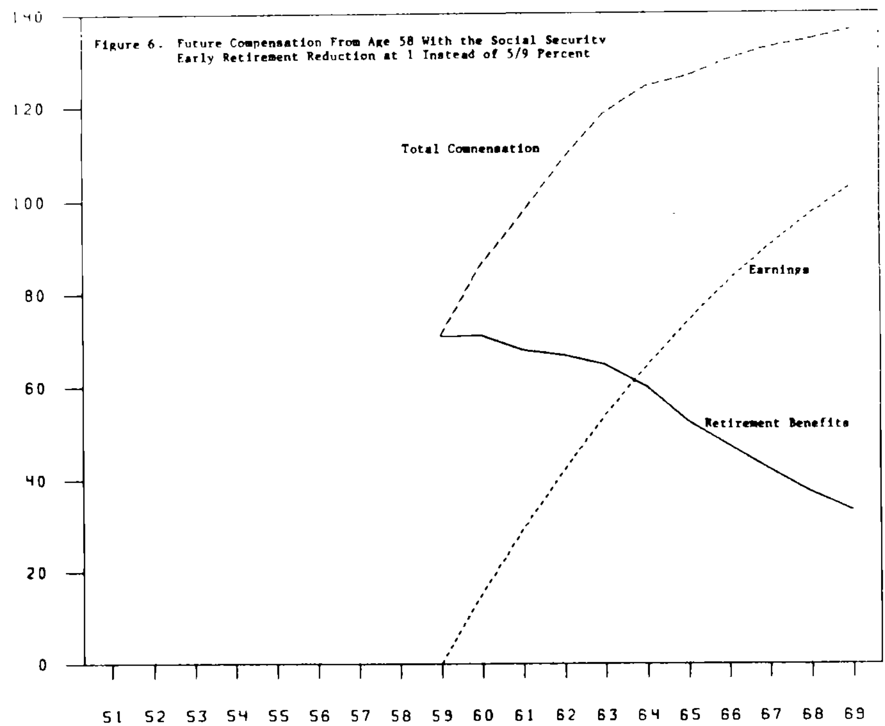


Figure 6. Future Compensation From Age 58 With the Social Security Early Retirement Reduction at 1 Instead of 5/9 Percent



provisions are described here.[4] An employee could leave the firm at age 53, for example. If he were to do that, and if he were vested in the firm's pension plan-- which occurs after 10 years of service--he would be entitled to normal retirement pension benefits at age 65, based on his years of service and current dollar earnings at age 53. He could start to receive benefits as early as age 55, the pension early retirement age, but the benefit amount would be reduced actuarially. If he started to receive benefits at age 55, they would be only 36 percent of dollar amount he would receive at age 65. If, however, he were to remain in the firm until the early retirement age, the situation would be quite different. He would be entitled to normal retirement benefits based on his years of service and salary at age 55. But, if he were to start to receive them at age 55, the benefits would be reduced less than actuarially, about 3 percent for each year that retirement precedes age 65, instead of 6 or 7 percent. In addition, the plan has a Social Security offset provision. Pension benefits are offset by a specified amount, depending on the firm estimate of Social Security benefits. But if the person takes early retirement, between 55 and 65, the Social Security offset is not applied to benefits received before age 65. These two provisions create the large discontinuous jump in retirement benefits at age 55; there is an enormous bonus for remaining with the firm until that age. After age 55, however, the person who does not retire foregoes the opportunity of taking pension benefits on very advantageous terms. Thus the minimal change in the discounted value of benefits between 55 and 60. If, a person has 30 years of service at age 60, he is entitled to full normal retirement benefits. No early retirement

[4]Full details of the plan provisions are presented in Kotlikoff and Wise [1987].

reduction is applied to benefits if they are taken then. That is, by continuing to work he will no longer gain from fewer years of early retirement reduction, as he did before age 60. Thus the kink in the profile and the decline thereafter.

The top line shows total compensation. The large jump at 55 reflects the early retirement provisions of the pension plan. Total compensation declines modestly each year through age 60 and very rapidly thereafter. After age 62 or 63, total compensation is close to zero. Under these circumstances, it would be surprising if this person were to continue to work until age 65.

The graph can also be used to motivate the option value model used in the subsequent analysis. Suppose that the person depicted in figure 1 is considering whether to retire now, at age 50. If he does he will receive utility indirectly from the retirement benefits that he will receive until he dies. (In fact, he will not be able to receive firm pension benefits until age 55 and Social Security benefits can not be taken until age 62.) If he leaves the firm at age 50, though, he foregoes the option of retiring at some future age. In this case, there will be a large increase in pension benefits at age 55, and thus a jump in total lifetime income, if he postpones retirement until then. Some later age may be even more advantageous. In particular, if he does not retire, he maintains the option of retiring at the future age that for him yields the highest expected utility. The central feature of the option value model is that the person will postpone retirement at age 50 if, based on his expectations at age 50, the best of the future possibilities is better than retiring now. That is he postpones retirement if the value of the option to retire later exceeds the value of retiring today. At each subsequent age, he will make the same comparison. At some age, future retirement possibilities will look worse than immediate retirement and he will leave the firm.

It is clear that the early retirement provisions in this firm are likely to have an important effect on retirement decisions. The qualitative effect of changing the early retirement age can be seen by comparing figures 1 and 2. Figure 2 describes the expectations of the same person considered in figure 1, except that the firm early retirement age has been shifted from 55 to 60, with all other plan provisions remaining unchanged. It is apparent that the person would under these provisions be much less likely to retire before age 60. Estimates of the actual effects of such a change are presented below.

To calculate the amounts graphed in figures 1 and 2, future income is discounted at a 5 percent real interest rate, and, no distinction is made between individual valuation of wage earnings versus pension benefits. To predict retirement, however, the relevant values are not these, but rather the discounted value of future utilities based on the weights that individuals assign to future income streams in determining whether to retire. Such values are estimated in the subsequent analysis. As it turns out, the estimated discount factor is much higher than 5 percent, and individuals value a dollar of retirement benefits much more than a dollar of wage earnings; a dollar without work is better than a dollar with work. Based on our parameter estimates, the graph, from the point of view of the individual, would look like figure 3 instead of figure 1. Based on these valuations of future income streams, the person depicted in figure 1 would be much more likely to retire before age 60 say, than is in fact suggested by figure 1.

Persons of the same age face very different options depending on years of service and earnings histories. A comparison of figures 1 and 4 demonstrates this point. The person whose expected future options are shown in figure 4 has only three years of service when he is 50 years old. He will not have 30 years of service until he is 77. He will not be vested until he is 57. Compared to the person in figure 1, this person would apparently be much less likely to retire before age 65.

Finally, consider a person who is still working at age 58 in 1980. He has 18 years of service. His expected future options are shown in figure 5. Although his wage earnings will decrease only slightly in the next 10 years, the present value of retirement benefits will decline almost continuously. The graph suggests that retirement would be likely around 63 or 64. It was clear from a comparison of figures 1 and 2 that changing the firm early retirement age from 55 to 60 would have a substantial effect on retirement. The potential effect of changes in Social Security provisions can be seen by altering the options faced by the person described in figure 5. The current Social Security rules reduce benefits by 5/9 of a percent for each month that benefits are taken before age 65. Suppose that the reduction were 1 percent per month instead of 5/9. The effect on the options faced by the figure 5 person are shown in figure 6. The effect is noticeable, but not extreme. The value of retirement benefits before age 65 has been shifted downward, and thus total income associated with retirement before age 65 has been shifted down. The result would apparently be a lower likelihood of retirement between 62 and 65, judging by the change in the graph. Actual estimates of the effect of such a change in Social Security provisions are presented below.

II. <u>The Option Value Model</u>

The details of the option value model are set forth in this section. Antecedents for the model begin with Lazear and Moore [1988], who argue that the option value of postponing retirement is the appropriate variable to enter in a regression equation explaining retirement. Indeed, it was their work, and analysis of military retirement rates by Phillips and Wise [1987], that motivated us to pursue this approach. Our model is also close in spirit to the much more complicated dynamic programming model of Rust [1988]. A dynamic programming model of employment behavior has also been proposed by Berkovec and Stern [1988].

To begin, consider the expected gain at age t from postponing retirement to age r. We denote it by

$$(1) \qquad G_t(r) = E_tV_t(r) - E_tV_t(t) \ ,$$

where $E_tV_t(r)$ is the expected value from working through age r-1 and retiring at age r, and $E_tV_t(t)$ is the expected value associated with current retirement. Suppose that r^* is the value of r that maximizes (1). The person postpones retirement at age t if $G_t(r^*) > 0$. That is,

$$(2) \qquad \text{Postpone retirement if } G_t(r^*) = E_tV_t(r^*) - E_tV_t(t) > 0 \ .$$

If $G_t(r^*) < 0$, the person retires at age t. Thus $G_t(r)$ is the retirement decision function.

The value function V depends on future earnings and on firm pension and Social Security benefits after retirement. More precisely, V depends on the indirect utility from future earnings and retirement benefits. It is described by

$$(3) \qquad V_t(r) = \sum_{s=t}^{r-1}\beta^{s-t}U_w(Y_s) + \sum_{t=r}^{S}\beta^{s-t}U_r(B_s(r)) \ .$$

If the person continues to work, his wage earnings in year s are given by Y_s and the indirect utility from these earnings by $U_w(Y_s)$. The weight assigned to future utility, in the determination of the retirement decision, is β. If he retires in year r, he will receive retirement benefits $B_s(r)$ in subsequent years s, which he values according to the function $U_r(B_s(r))$. As explained above, a person's retirement benefits will depend on his age and years of service at the time of retirement r, as well as his earnings history; thus the notation indicating that B_s is a function of r. (We adopt the convention that if s is the first calendar year during which the person has no wage earnings, he is assumed to have retired at the age that he was on January 1 of year s.)

The two utility functions are specified as

$$U_w(Y_s) = Y_s^{\gamma} + \omega_s$$

(4)

$$U_r(B_s) = (kB_s(r))^{\gamma} + \xi_s$$

where ω_s and ξ_s are individual-specific random effects. The parameter k is to recognize the possibility that a dollar with leisure -- while retired -- is better than a dollar that is only had together with work. The random terms reflect a variety of unobserved differences among individuals. The values that individuals attach to wage and pension income may differ. Some persons may enjoy work more than others; some may enjoy retirement more than others. Both may be affected by health status, for example. Retirement decisions are likely to be affected by assets, other than pension wealth, which we do not measure. Such differences will be reflected in different values of ξ. In addition, we consider retirement to be the alternative to continued employment with the firm. For some, especially the younger persons in the sample, the alternative may well be another job. The utility of the alternative to work in such cases will presumably be greater than the utility represented by $U_r(B_s)$ for the typical person. These differences too will be reflected in different values of ξ. (The heteroskedastic error structure that the model implies, as explained below, is well suited to capture the effects of alternatives other than retirement, with the likelihood of such an alternative greatest for younger employees.)

Differences in preferences for work versus retirement, differences in health status, and other individual differences are likely to persist. Thus these terms are assumed to follow a random walk over time. That is,

$$\omega_s = \omega_{s-1} + \epsilon_{\omega s} \, , \; E_{s-1}(\epsilon_{\omega s}) = 0,$$

(5)

$$\xi_s = \xi_{s-1} + \epsilon_{\xi s} \, , \; E_{s-1}(\epsilon_{\xi s}) = 0,$$

We adopt the convention that at time s the individual knows ω_s and ξ_s; his future forecasts of ω and ξ are based on (5). The random walk assumption means, for example, that if a person's health status worsens between periods t and t+1, his expected health status in period t+2 is not what it was in period t, but rather what it was in period t+1.

With the substitution of the specifications (3) and (4), $G_t(r)$ may be decomposed into two terms, one depending on the individual-specific random terms ω_s and ξ_s, and the other depending only on measured variables. We have

$$
\begin{aligned}
G_t(r) = {} & E_t\textstyle\sum_{s=t}^{r-1}\beta^{s-t}(Y_s^\gamma) + E_t\sum_{s=r}^{S}\beta^{s-t}(kB_s(r))^\gamma \\
& - E_t\textstyle\sum_{s=t}^{S}\beta^{s-t}(kB_s(t))^\gamma \\
& + E_t\textstyle\sum_{s=t}^{r-1}\beta^{s-t}\omega_s + E_t\sum_{s=r}^{S}\beta^{s-t}\xi_s \qquad (6)\\
& - E_t\textstyle\sum_{s=t}^{S}\beta^{s-t}\xi_s \\
= {} & g_t(r) + \phi_t(r)
\end{aligned}
$$

where $g_t(r)$ and $\phi_t(r)$ distinguish the random effect terms from the other terms.

To evaluate these terms, it is necessary to account for the likelihood that a person will be alive to collect pension benefits, or to earn a wage, in future years. If this probability is independent of his earnings stream and the individual random effects, $g_t(r)$ and $\phi_t(r)$ become

$$
\begin{aligned}
g_t(r) = {} & \textstyle\sum_{s=t}^{r-1}\beta^{s-t}\pi(s|t)E_t(Y_s^\gamma) \\
& + \textstyle\sum_{s=r}^{S}\beta^{s-t}\pi(s|t)[E_t(kB_s(r))^\gamma] \qquad (7)\\
& - \textstyle\sum_{s=t}^{S}\beta^{s-t}\pi(s|t)[E_t(kB_s(t))^\gamma]
\end{aligned}
$$

and

$$
\phi_t(r) = \textstyle\sum_{s=t}^{r-1}\beta^{s-t}\pi(s|t)E_t(\omega_s-\xi_s), \qquad (8)
$$

where $\pi(s|t)$ denotes the probability that the person will be alive in year s, given that he is alive in year t. Given the random walk assumption (5), $\phi_t(r)$ can be written as

$$(9) \qquad \phi_t(r) = [\textstyle\sum_{s=t}^{r-1}\beta^{s-t}\pi(s|t)](\omega_t - \xi_t)$$
$$= K_t(r)\nu_t \ ,$$

where $K_t(r) = \sum_{s=t}^{r-1}\beta^{s-t}\pi(s|t)$ and $\nu_t = \omega_t - \xi_t$. The simplification results from the fact that at time t the expected value of $\nu_s = \omega_s - \xi_s$ is ν_t, for all future years s; thus the individual random component $\phi_t(r)$ depends only on the random effect at time t. The term $K_t(r)$ cumulates the deflators that yield the present value in year t of the future expected values of the random components of utility. The further r is in the future, the larger is $K_t(r)$. That is, the more distant the potential retirement age, the greater the uncertainty about it. This yields a heteroskedastic disturbance term.

In short, $G_t(r)$ may be written simply as

$$(10) \qquad G_t(r) = g_t(r) + K_t(r)\nu_t \ .$$

The probability of retirement is easily described using this expression. If the person is to retire in year t, $G_t(r)$ must be less than zero for every potential retirement age r in the future. If $r^\dagger$ is the r that yields the maximum value of $g_t(r)/K_t(r)$, the probability of retirement becomes

$$(11) \qquad \Pr[\text{Retire in year t}] = \Pr[g_t(r^\dagger)/K_t(r^\dagger) < -\nu_t] \ .$$

To predict whether a person in the sample in year t-1 retires in year t, equation (11) is all that is needed. Finally, we assume that ν_t is normally distributed with variance σ_ν^2. The parameters to be estimated are γ, k, r (where $\beta = 1/(1+r)$), and σ_ν.

In fact, we are able to follow persons in the sample for 5 consecutive years. The analysis in this paper, however, is based only on data for one year. Retirement probabilities for several years may be derived as a simple extension of (11); they are shown in Stock and Wise [1988], together with estimates based on several consecutive years for each person.[5]

III. Parameter Estimates and The Model Fit

Evaluation of $g_t(r)/K_t(r)$ requires estimates of future earnings. Individual earnings forecasts are based on a second order autoregression that recognizes individual differences in earnings potential and accounts for past evidence of earnings increases. The autoregression was estimated using the individual earnings histories of all salesmen employed at least three years, with earnings converted to 1980 dollars using the Consumer Price Index. The parameters of the forecasting model depend on age, years of service, and an interaction term.[6]

The option value model parameter estimates and standard errors are:[7]

γ	k	β	$\sigma_\nu(\times 10^5)$	$\mathcal{L}$
1.00	1.66	0.847	0.119	-397.72
(0.07)	(0.02)	(0.032)	(0.001)	

---

[5]In fact, the estimates based on several years are very close to those reported here. Implementation using two or more consecutive years is only slightly more complicated than the exposition here, with $\nu_s = \nu_{s-1} + \epsilon_s$, ϵ_s i.i.d. $N(0,\sigma_\epsilon^2)$, ν_t i.i.d. $N(0,\sigma_\nu^2)$, where ν_t and ϵ_s, $s=t+1,\ldots,S$ are independent. The covariance between ν_τ and $\nu_{\tau+1}$ is $var(\nu_\tau)$, and the variance of ν_τ for $\tau \geq t$ is $\sigma_\nu^2 + (\tau-t)\sigma_\epsilon^2$. (See Stock and Wise [1988].)

[6]For more detail see Stock and Wise [1988].

[7]The estimates were obtained by maximum likelihood, using 1500 observations.

All of the parameters are measured quite precisely, with the possible exception of the weight β. The estimated γ of 1 means that the value function V is linear in income. This evidence rejects a log-linear value function, for example. The estimated value of k means that a dollar without work is worth 1.66 times a dollar gotten by working. In other words, the typical person would be willing to exchange a dollar with work for 60 cents without work. This suggests, loosely interpreted, that retirement benefits that replaced 60 percent of wage earnings would make a person indifferent between work and retirement. In the retirement decision, the estimated weight given to income one year in the future versus now is .847; income five years hence is given about half as much weight as income today. The variance term σ_{ν}, \$11,900, should be interpreted relative to the present value of future income. Typical values are indicated by the graphs at the beginning of the paper.

The model fits the data very well. First, consider three likelihood values:

Prediction Method	$\mathcal{L}$
Using the sample average retirement probability	-579.6
Using average probability for each age	-477.9
Using the model estimates	-397.7

Comparison of the second and third values shows that retirement probabilities based on the model fit the data much better than predictions that would be obtained by using a dummy variable for each age. One might assume that using the sample average retirement rate for each age would provide very good predictions. But what the comparison reflects is that retirement probabilities vary a great deal among persons of the same age. That this was likely to be true was evident from the graphs at the beginning of the paper.

In addition, the probabilities for any age group depend strongly on discounted future income streams, as cumulated in the model. Thus the model with only four parameters performs better than a model with 17 age dummy variables that ignores differences in expected future income streams among persons of the same age. Unlike other models of retirement, age enters the option value model only indirectly -- through the survival probabilities, the earnings forecasts, and the firm pension plan and Social Security rules.

Another way to understand the model fit is to compare actual versus predicted retirement rates. These are shown in table 1 and in figure 7. There are large jumps in the actual retirement rates at specific ages: 55, 60, and 62. All are matched very closely by the model predictions. Both the actual and predicted rates are 8 percent at age 55. One is 22, the other 19 at age 60. One is 46, the other 45 at age 62. Beyond age 64 the sample sizes are too small to make reliable comparisons. The proportion of those in the firm at age 50 that would remain at age 54, based on actual retirement rates, is .14; the predicted proportion is .12. This suggests that even though measured variables may often not evaluate correctly the alternative to continued work in the firm for younger employees, the error specification allows enough flexibility that the model predictions are still quite accurate. At older ages, the model predicts almost precisely the proportion of employees who have left the firm, as shown in figure 7.

We have also used the model to predict retirement rates in 1981 for persons in the sample who did not retire in 1980. The results are shown in table 2. The interesting feature of this comparison is that retirement rates at 59, 60, and 61 were considerably higher in 1981 than in 1980. Nonetheless, the model matches the actual rates very closely. Presumably the different retirement rates were due to different predictions about future earnings in

Table 1

Predicted and Actual Retirement Rates by Age for 1980[a]

Age	Number of Observations	Retirement Rates Actual	Retirement Rates Predicted	Cumulative Rates Actual	Cumulative Rates Predicted
50.000	36.000	0.000	0.025	0.000	0.025
51.000	131.000	0.053	0.037	0.053	0.061
52.000	132.000	0.015	0.026	0.068	0.086
53.000	123.000	0.041	0.024	0.106	0.108
54.000	106.000	0.038	0.009	0.139	0.116
55.000	129.000	0.078	0.075	0.206	0.182
56.000	137.000	0.117	0.073	0.299	0.241
57.000	123.000	0.089	0.108	0.362	0.323
58.000	107.000	0.084	0.102	0.415	0.392
59.000	120.000	0.125	0.149	0.488	0.483
60.000	116.000	0.216	0.194	0.599	0.583
61.000	84.000	0.190	0.233	0.675	0.680
62.000	70.000	0.457	0.447	0.824	0.823
63.000	51.000	0.412	0.503	0.896	0.912
64.000	22.000	0.455	0.491	0.943	0.955
65.000	14.000	0.857	0.468	0.992	0.976
66.000	1.000	0.000	0.355	0.992	0.985

[a]The retirement rates were computed for the 1500 persons used to estimate the model.

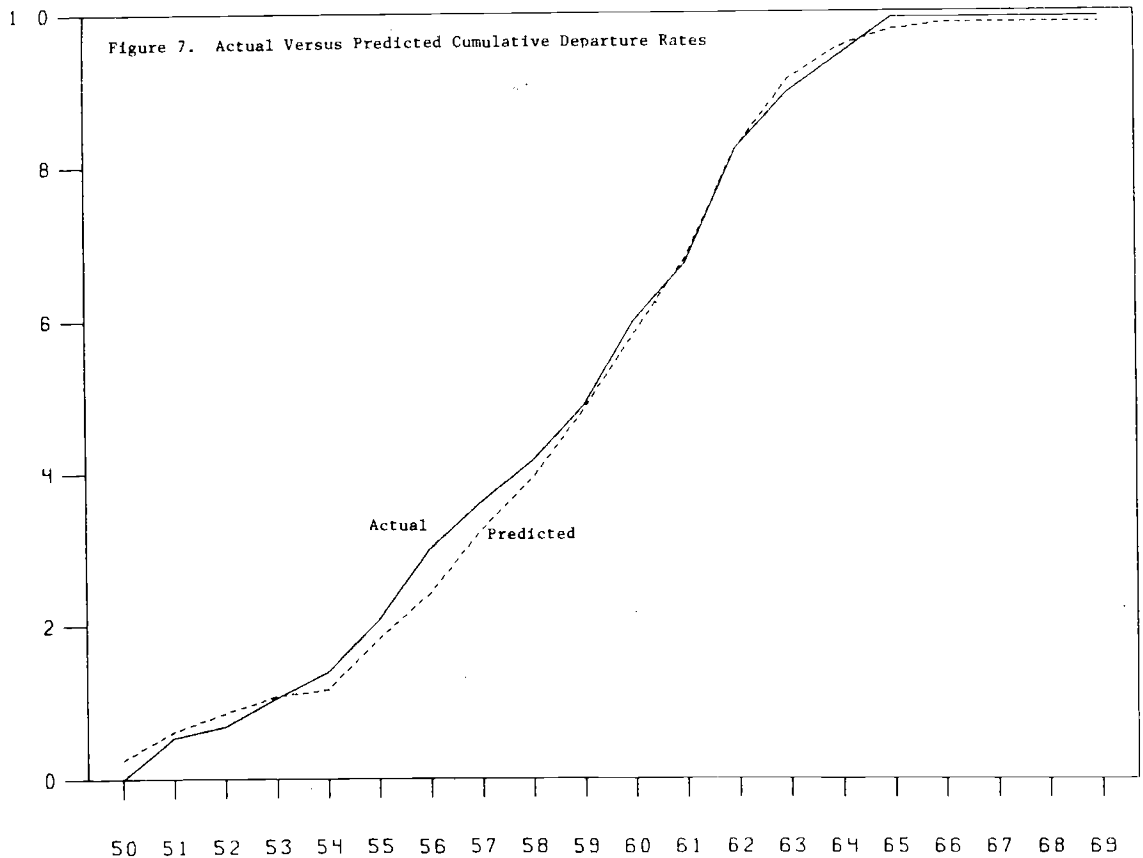


Figure 7. Actual Versus Predicted Cumulative Departure Rates

Table 2

Out-of-Sample Predictions for 1981

Age	Number of Observations	Retirement Rates		Cumulative Rates	
		Actual	Predicted	Actual	Predicted
50.000	0.000	0.000	0.000	0.000	0.000
51.000	36.000	0.056	0.033	0.056	0.033
52.000	124.000	0.040	0.033	0.094	0.065
53.000	130.000	0.046	0.021	0.135	0.085
54.000	118.000	0.042	0.014	0.172	0.098
55.000	102.000	0.088	0.079	0.245	0.168
56.000	119.000	0.126	0.115	0.340	0.264
57.000	121.000	0.074	0.101	0.389	0.338
58.000	112.000	0.107	0.147	0.455	0.435
59.000	98.000	0.173	0.165	0.549	0.528
60.000	105.000	0.276	0.293	0.674	0.667
61.000	91.000	0.231	0.244	0.749	0.748
62.000	68.000	0.471	0.504	0.867	0.875
63.000	38.000	0.447	0.447	0.927	0.931
64.000	30.000	0.367	0.540	0.954	0.968
65.000	12.000	0.833	0.531	0.992	0.985
66.000	2.000	0.000	0.200	0.992	0.988
67.000	1.000	0.000	0.297	0.992	0.992

the firm that the model captures, or to differences in the distribution of employees by age and years of service, that also enter the model calculations. From the earnings regression, it is evident that future earnings prospects changed significantly from one year to the next. The model underestimates a bit the departure rates of persons under 55. Again, the model predictions are much better than predictions based on age-specific retirement rates, as shown by the following likelihood values:

Prediction Method	$\mathcal{L}$
Using the sample average retirement probability	-559.3
Using average probability for each age	-473.9
Using the model estimates	-404.4

IV. Simulations of the Effects of Changes in Pension and SS Provisions

We have used the model to simulate the effect of several potential changes in the firm pension plan and in Social Security provisions. We conclude that potential changes in the firm pension plan have a much greater effect on retirement rates than changes in Social Security rules. Four changes are considered:

A. Increase the Firm Early Retirement Age from 55 to 60

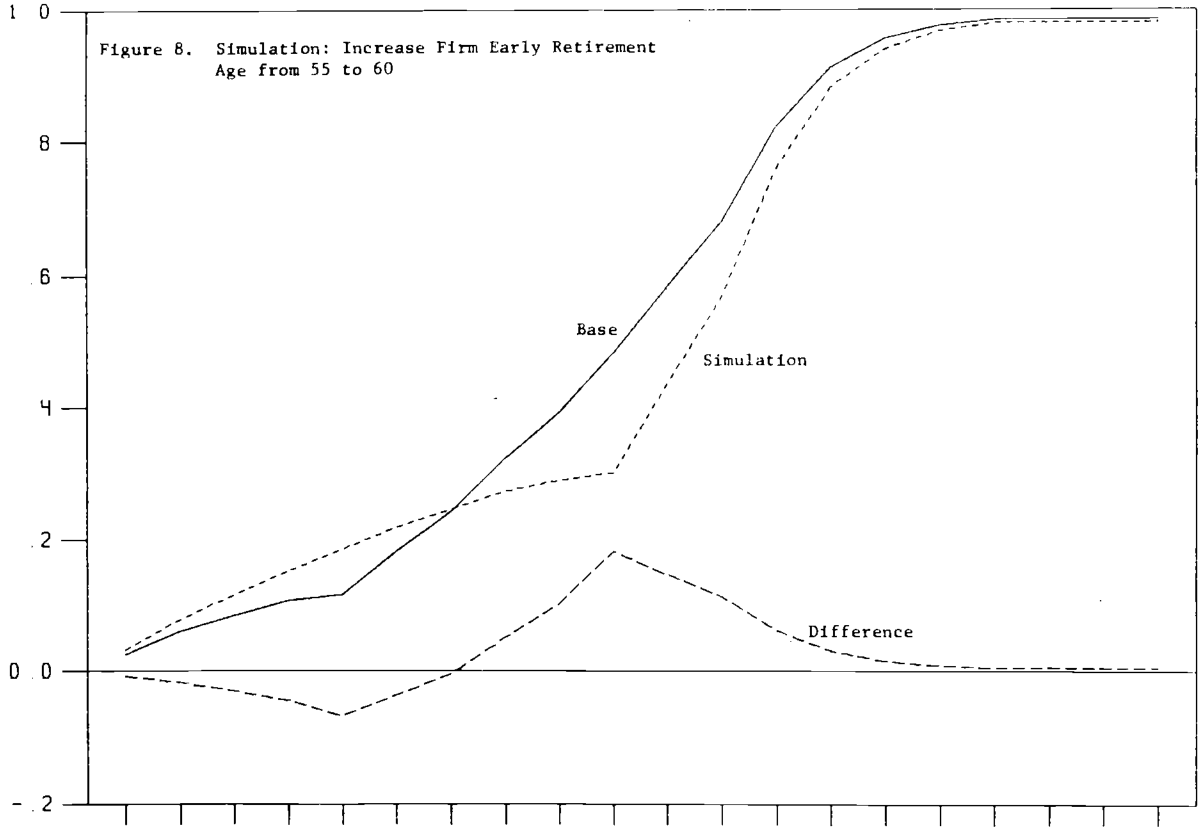
The effect of increasing the firm's early retirement age from 55 to 60, leaving other provisions as they were, is shown in table 3, and is graphed in figure 8. Under the current plan 48 percent of those employed at 50 have left by 59. Only 30 percent would have left by age 59 if early retirement had been at 60 instead of 55. Only 11.5 percent of employees leave between 55 and 59 if early retirement is at 60, whereas 36.7 percent leave between these ages under the current system. On the other hand, because the early retirement

Table 3

Simulation: Increase the Firm Early Retirement Age
From 55 to 60

	Retirement Rates			Cumulative Rates		
Age	Base	Simulation	Difference	Base	Simulation	Difference
50.000	0.025	0.032	0.007	0.025	0.032	0.007
51.000	0.037	0.047	0.011	0.061	0.078	0.017
52.000	0.026	0.041	0.015	0.086	0.116	0.030
53.000	0.024	0.041	0.017	0.108	0.153	0.045
54.000	0.009	0.038	0.029	0.116	0.185	0.069
55.000	0.075	0.041	-0.033	0.182	0.219	0.037
56.000	0.073	0.034	-0.038	0.241	0.245	0.004
57.000	0.108	0.036	-0.072	0.323	0.272	-0.051
58.000	0.102	0.023	-0.079	0.392	0.289	-0.103
59.000	0.149	0.015	-0.133	0.483	0.300	-0.182
60.000	0.194	0.194	0.000	0.583	0.436	-0.147
61.000	0.233	0.233	0.000	0.680	0.568	-0.113
62.000	0.447	0.447	0.000	0.823	0.761	-0.062
63.000	0.503	0.503	0.000	0.912	0.881	-0.031
64.000	0.491	0.491	0.000	0.955	0.939	-0.016
65.000	0.468	0.468	0.000	0.976	0.968	-0.008
66.000	0.355	0.355	0.000	0.985	0.979	-0.005

Figure 8. Simulation: Increase Firm Early Retirement Age from 55 to 60



"bonus" is now farther in the future, more employees leave the firm between 50 and 54. This is the result of the greater weight given to current versus future income. In short, many more workers would be employed between the ages of 57 and 65 if the early retirement age were 60 instead of 55.

B. Increase the SS Early Retirement Reduction Factor

The current Social Security rules include a benefit reduction of 5/9 percent per month of retirement before age 65. We consider the effect of increasing the reduction factor to 1 percent per month. The results are shown in table 4 and graphically in figure 9. It is clear that the effect of this change is small relative to the effect of the change in the firm early retirement age. This is primarily because only a small fraction of firm employees are still working at age 62, only 18 percent in the base case. The retirement rates of those still employed at age 62, however, are considerably lower -- about 21 percent -- with the higher reduction factor. They are also lower at 63. Still, the net result on the employment of persons covered by the firm's pension plan is negligible.

C. Increase the SS Retirement Ages by One Year

Current plans are to increase the Social Security retirement age from 65 to 67 by 2027. To judge the effect of such a change on workers with pension plans like the one in our firm, we simulate the effect of increasing the normal retirement age from 65 to 66 and the early retirement age from 62 to 63. The results are in table 5 and in figure 10. Again, the effect on the retirement rates of persons in our firm is small. This is true even though the effect on the annual retirement rates of 62 and 65 year olds is substantial. The retirement rate of 62-year-olds is reduced from 44.7 to 33.2

Table 4

Simulation: Increase of Social Security Early Retirement Reduction Factor

	Retirement Rates			Cumulative Rates		
Age	Base	Simulation	Difference	Base	Simulation	Differenc
50.000	0.025	0.026	0.000	0.025	0.026	0.000
51.000	0.037	0.037	0.000	0.061	0.062	0.001
52.000	0.026	0.026	0.000	0.086	0.086	0.001
53.000	0.024	0.024	0.000	0.108	0.109	0.001
54.000	0.009	0.010	0.000	0.116	0.117	0.001
55.000	0.075	0.075	0.001	0.182	0.184	0.002
56.000	0.073	0.074	0.001	0.241	0.244	0.003
57.000	0.108	0.108	0.000	0.323	0.326	0.003
58.000	0.102	0.102	0.000	0.392	0.395	0.003
59.000	0.149	0.149	0.001	0.483	0.485	0.003
60.000	0.194	0.195	0.001	0.583	0.586	0.003
61.000	0.233	0.235	0.001	0.680	0.683	0.003
62.000	0.447	0.354	-0.092	0.823	0.795	-0.028
63.000	0.503	0.437	-0.066	0.912	0.885	-0.027
64.000	0.491	0.466	-0.025	0.955	0.938	-0.017
65.000	0.468	0.468	0.000	0.976	0.967	-0.009
66.000	0.355	0.355	0.000	0.985	0.979	-0.006

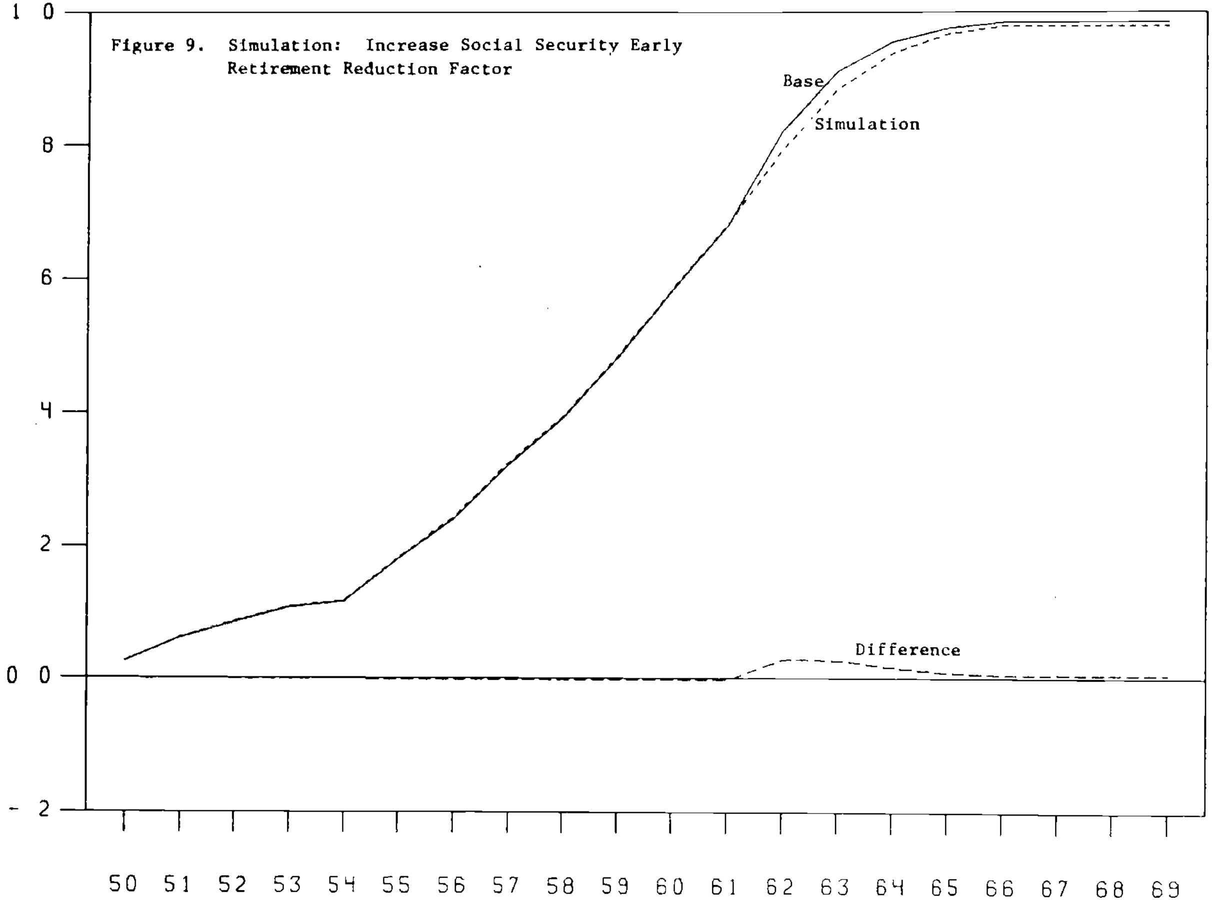


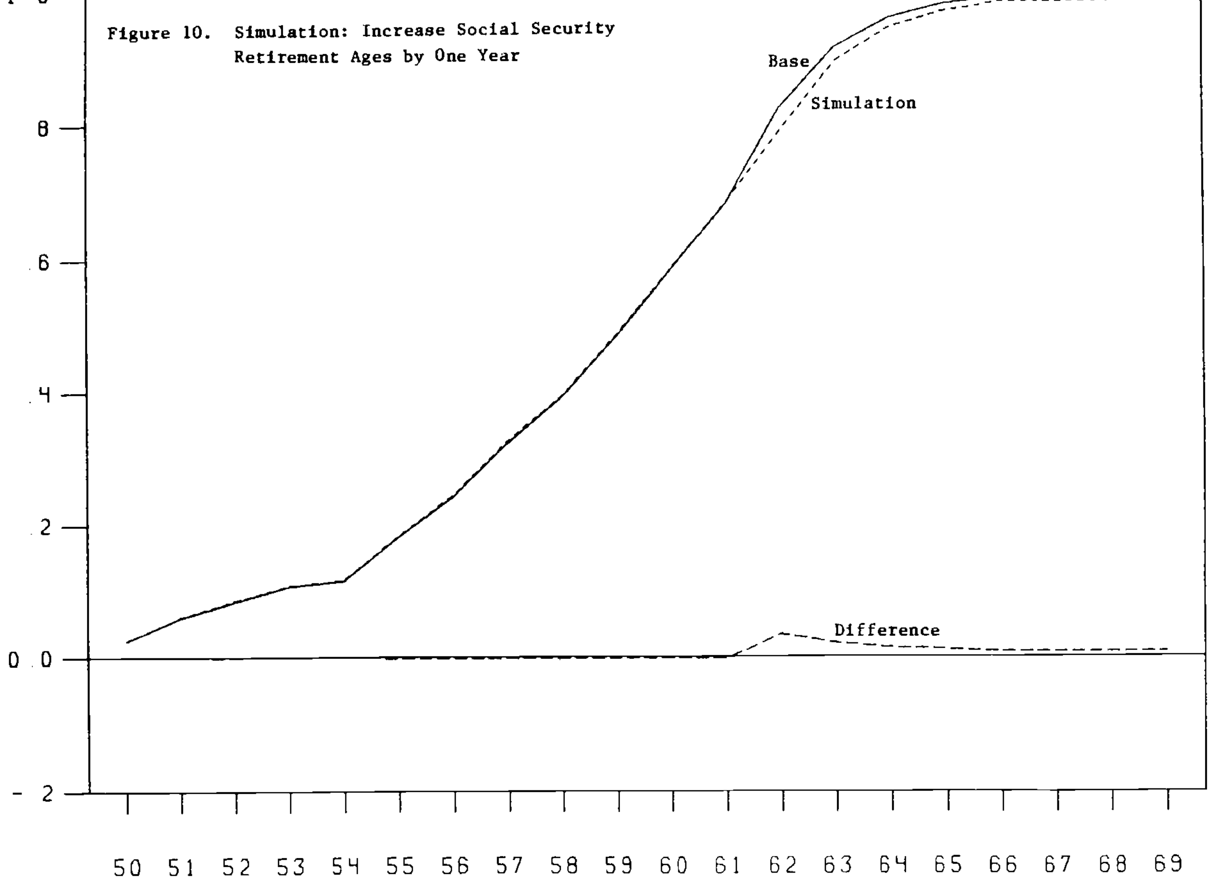
Figure 9. Simulation: Increase Social Security Early Retirement Reduction Factor

Table 5

Simulation: Increase the Social Security Retirement Age by One Year

Age	Retirement Rates			Cumulative Rates		
	Base	Simulation	Difference	Base	Simulation	Difference
50.000	0.025	0.026	0.000	0.025	0.026	0.000
51.000	0.037	0.037	0.000	0.061	0.062	0.001
52.000	0.026	0.026	0.000	0.086	0.086	0.001
53.000	0.024	0.024	0.000	0.108	0.109	0.001
54.000	0.009	0.010	0.000	0.116	0.117	0.001
55.000	0.075	0.075	0.001	0.182	0.184	0.002
56.000	0.073	0.074	0.001	0.241	0.244	0.002
57.000	0.108	0.108	0.000	0.323	0.326	0.002
58.000	0.102	0.102	0.000	0.392	0.395	0.002
59.000	0.149	0.149	0.001	0.483	0.485	0.002
60.000	0.194	0.195	0.001	0.583	0.585	0.002
61.000	0.233	0.235	0.001	0.680	0.683	0.002
62.000	0.447	0.332	-0.115	0.823	0.788	-0.035
63.000	0.503	0.483	-0.020	0.912	0.890	-0.022
64.000	0.491	0.462	-0.029	0.955	0.941	-0.014
65.000	0.468	0.402	-0.067	0.976	0.965	-0.011
66.000	0.355	0.354	-0.000	0.985	0.977	-0.007

Figure 10. Simulation: Increase Social Security Retirement Ages by One Year



percent. The rate at 65 is reduced from 46.8 to 40.2. But only a few workers remain in the firm to be affected by these changes.

D. Increase SS Retirement Ages by One Year and Start the SS Offset at 66

If the Social Security retirement age were increased to 66, the firm might be expected to begin the Social Security offset at 66 instead of 65. Thus we have simulated the effect of increasing the Social Security retirement ages by one year and beginning the Social Security offset to the firm pension benefits at 66 instead of 65. The result is reported in table 6 and shown graphically in figure 11. Increasing the Social Security retirement ages reduced retirement rates by a small amount, as shown in table 5. But even these small effects would essentially be counteracted if the firm were to respond by delaying the imposition of the Social Security offset. For example, increasing the Social Security retirement ages reduced the retirement rate at age 62 by .115; the reduction is only .030 if the Social Security action is accompanied by the firm response that we have simulated.

IV. Summary and Concluding Comments

The option value model developed in Stock and Wise [1988] has been used to simulate the effects on retirement of changes in a firm's pension plan and of changes in Social Security rules. Several important conclusions are supported by the analysis:

- The provisions of the firm's pension plan have a much greater effect than Social Security regulations on the retirement decisions of the firm's employees.
- Increasing the firm's early retirement age from 55 to 60, for example, would reduce by almost 40 percent, from .48 to .30, the fraction of employees that is retired by age 60.

Table 6

Simulation: Increase Social Security Retirement Ages by One Year and Start the Social Security Offset at 66

Age	Retirement Rates			Cumulative Rates		
	Base	Simulation	Difference	Base	Simulation	Difference
50.000	0.025	0.026	0.000	0.025	0.026	0.000
51.000	0.037	0.037	0.001	0.061	0.062	0.001
52.000	0.026	0.027	0.001	0.086	0.087	0.002
53.000	0.024	0.025	0.001	0.108	0.110	0.003
54.000	0.009	0.010	0.000	0.116	0.119	0.003
55.000	0.075	0.078	0.003	0.182	0.187	0.006
56.000	0.073	0.077	0.004	0.241	0.250	0.009
57.000	0.108	0.108	0.000	0.323	0.331	0.008
58.000	0.102	0.102	-0.000	0.392	0.399	0.007
59.000	0.149	0.148	-0.001	0.483	0.488	0.006
60.000	0.194	0.195	0.000	0.583	0.588	0.005
61.000	0.233	0.234	0.000	0.680	0.684	0.004
62.000	0.447	0.417	-0.030	0.823	0.816	-0.007
63.000	0.503	0.497	-0.006	0.912	0.907	-0.005
64.000	0.491	0.451	-0.040	0.955	0.949	-0.006
65.000	0.468	0.450	-0.019	0.976	0.972	-0.004
66.000	0.355	0.292	-0.062	0.985	0.980	-0.004

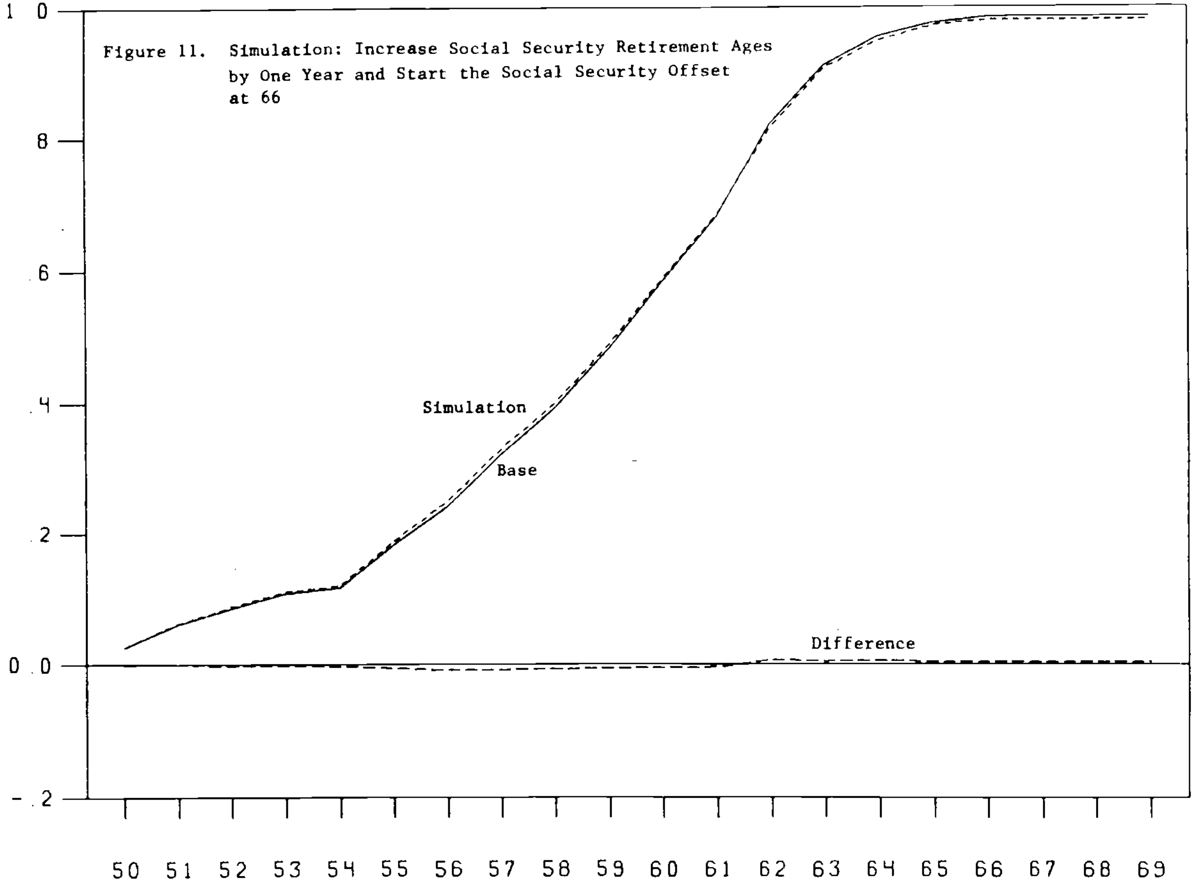


Figure 11. Simulation: Increase Social Security Retirement Ages by One Year and Start the Social Security Offset at 66

- The effect of changes in Social Security rules, on the other hand, would be small. Raising the Social Security retirement ages by one year, for example, has very little effect on employee retirement rates. The proportion retired by age 62 is reduced by only about 4 percent.
- Changes in Social Security provisions that would otherwise encourage workers to continue working can easily be offset by countervailing changes in the provisions of the firm's pension plan. Firm responses, like delaying the Social Security offset to correspond to a later Social Security retirement age, may simply be a logical revision of current firm plan provisions.

Thus in considering the effect of changes in Social Security rules, like the retirement age, it is important to understand the implications of private pension plan provisions. In particular, if the effect on retirement decisions of changes in Social Security rules is to be predicted the potential response of firms to the changes cannot be ignored.

Although the analysis is based on the retirement experience in a single large firm, the firm's pension plan is typical of defined benefit plans. Approximately 75 percent of the employees who are covered by a firm pension have defined benefit plans. Thus the results suggest that pension plans in general have had a very substantial effect on the labor force participation rates of older workers.

In addition to the simulations, the paper describes the option value model of retirement. Comparisons of actual versus predicted retirement rates demonstrate that the model predicts very complicated retirement patterns with considerable precision. That the model fits observed data well increases our confidence in the simulated results.

References

Berkovec, James and Steven Stern. 1988. "Job Exit Behavior of Older Men." Mimeograph.

Blinder, Alan, Roger Gordon, and Donald Wise. 1980. "Reconsidering the Work Disincentive Effects of Social Security," in *National Tax Journal*, Vol. 33, December, pp. 431-442.

Bulow, J. 1981. "Early Retirement Pension Benefits." NBER Working Paper No. 654.

Burkhauser, Richard V. 1980. "The Early Acceptance of Social Security: An Asset Maximization Approach," in *Industrial and Labor Relations Review*, Vol. 33, pp. 484-92.

Burkhauser, Richard V. 1979. "The Pension Acceptance Decision of Older Workers," in *Journal of Human Resources XIV(1)*, pp. 63-75.

Burtless, Gary. 1986. "Social Security, Unanticipated Benefit Increases, and the Timing of Retirement," in *Review of Economic Studies*, Vol. 53, October, pp. 781-805.

Burtless, Gary, and Robert A. Moffitt. 1984. "The Effects of Social Security on the Labor Supply of the Aged," in H. Aaron and G. Burtless (eds.) Retirement and Economic Behavior, pp. 135-174. Washington, D.C.: Brookings Institution.

Fields, Gary S. and Olivia Mitchell. 1982. "The Effects of Pensions and Earnings on Retirement: A Review Essay," in R. Ehrenberg (ed.) *Research in Labor Economics*, Vol. 5, pp. 115-156. Greenwich, CT: JAL Press.

Gustman, Alan and Thomas Steinmeier. 1986. "A Structural Retirement Model," in *Econometrica*, Vol. 54, pp. 555-584.

Hausman, Jerry A. and David A. Wise. 1985. "Social Security, Health Status, and Retirement," in D. Wise (ed.) Pensions, Labor, and Individual Choice, pp. 159-190. Chicago: University of Chicago Press.

Hogarth, Jeanne M. 1988. "Accepting an Early Retirement Bonus: An Empirical Study," in *Journal of Human Resources XXIII(1)*, pp. 21-33.

Hurd, Michael and Michael Boskin. 1981. "The Effect of Social Security on Retirement in the Early 1970s," in *Quarterly Journal of Economics*, November, pp. 767-790.

Kotlikoff, Laurence J. and David A. Wise. 1985. "Labor Compensation and the Structure of Private Pension Plans: Evidence for Contractual versus Spot Labor Markets," in D. Wise (ed.) Pensions, Labor, and Individual Choice, pp. 55-87. Chicago: University of Chicago Press.

Kotlikoff, Laurence J. and David A. Wise. 1987. "The Incentive Effects of Private Pension Plans," in Z. Bodie, J. Shoven, and D. Wise (eds.) Issues in Pension Economics, pp. 283-339. Chicago: University of Chicago Press.

Kotlikoff, Laurence J. and David A. Wise. 1988. "Employee Retirement and A Firm's Pension Plan." NBER working paper no. 2323. Forthcoming in D. Wise (ed.) The Economics of Aging. Chicago: University of Chicago Press.

Lazear, Edward P. 1983. "Pensions as Severance Pay," in Z. Bodie and J. Shoven (ed.) Financial Aspects of the United States Pension System. Chicago: University of Chicago Press.

Lazear, Edward P. and Robert L. Moore. 1988. "Pensions and Turnover," in Z. Bodie, J. Shoven, and D. Wise (eds.) Pensions in the U.S. Economy, pp. 163-188. Chicago: University of Chicago Press.

Phillips, Douglas and David A. Wise. 1987. "Military versus Civilian Pay: A Descriptive Discussion," in D. Wise (ed.) Public Sector Payrolls, pp. 19-46. Chicago: University of Chicago Press.

Rust, John. 1988. "A Dynamic Programing Model of Retirement Behavior." NBER working paper no. 2470. Forthcoming in D. Wise (ed.) The Economics of Aging. Chicago: University of Chicago Press.

Stock, James H. and David A. Wise. 1988. "Pensions, the Option Value of Work, and Retirement." Working paper.