ELSEVIER

Journal of Health Economics 17 (1998) 171–185

JOURNAL OF HEALTH ECONOMICS

The effect of uncertainty on the demand for medical care, health capital and wealth

Gabriel Picone [a,*], Martín Uribe [b], R. Mark Wilson [a]

[a] *University of South Florida, Tampa, FL, USA*
[b] *Board of Governors of the Federal Reserve System, [illegible], USA*

Received 30 April 1997; accepted 31 July 1997

Abstract

We analyze the effect of the uncertainty of the incidence of illness on the demand for medical care and on the accumulation of health capital and wealth over the retirement years. We use a simplified version of a dynamic Grossman household production model to characterize patterns of an individual's precautionary behavior. Elderly individuals respond to uncertainty by smoothing their expected utility over time by making specific patterns of purchases of medical care and consumption. We examine these patterns for individuals with different degrees of risk aversion. © 1998 Elsevier Science B.V.

Keywords: Medical care expenditures; Uncertainty; Precautionary behavior; Dynamic modeling

1. Introduction

Will I catch the flu this year? Will I have another heart attack? Will I develop cancer as some of my relatives have? One of the main features that distinguishes the demand for medical care from the demand for other goods and services is the

* Corresponding author. Department of Economics, College of Business Administration, University of South Florida, 4202 E. Fowler Avenue, Tampa, FL 33620. Tel.: +1-813-974-6537; fax: +1-813-974-6510; e-mail: gpicone@bsn01.bsn.usf.edu.

PII S0167-6296(97)00028-3

uncertainty of the incidence of illness. Individuals respond to this uncertainty by modifying their behavior, perhaps purchasing extra medical care and saving a little more each year as a precaution against future periods of illness. Very few studies focus on the direct effect of uncertainty on the demand for medical care (Dardanoni and Wagstaff, 1987, 1990; Selden, 1993; Chang, 1996), and none approach the topic within a framework that provides a description of the pattern of an individual's precautionary behavior over time.

In this paper we analyze the effect of the uncertainty of the incidence of illness on the precautionary behavior of individuals in their retirement years within a stochastic dynamic model based on the Grossman (1972) consumption model. We extend the work of Dardanoni and Wagstaff (1990) who examine the effect of uncertainty within a static version of the Grossman consumption model and find that, under plausible assumptions, greater uncertainty results in an increase in the demand for medical care. It is difficult for a static model to fully describe the effects of uncertainty because individuals do not make a one-time change in their behavior, but rather they make adjustments over time. To our knowledge ours is the first study to analyze the effects of this uncertainty on the demand for medical care in a dynamic framework.

Our model is a simplified version of the Grossman household production model with discrete time. We modify his model by introducing the uncertainty of the incidence of illness as described by Arrow (1963) and by making the optimization problem a result of a series of sequential decisions rather than one large maximization. The sequential decisions reflect the fact that an individual's current demand for medical care depends in part on previous decisions and on his/her uncertain expectations of the future. Our model characterizes an individual's purchases of medical care as the optimal path of expenditures that result from these decisions. Because this model does not have an analytical solution, we cannot obtain standard comparative static results. Instead, we solve the model numerically and derive the time paths of the endogenous variables, consumption and medical care expenditures, as well as the state variables, wealth and health capital. To assess the effects of uncertainty we change selected parameters and obtain time paths that can be compared to the original paths.

An advantage of our method is that it allows us to characterize the response to uncertainty as a pattern of precautionary behavior rather than as a one time change in medical care. We find that individuals adjust their behavior over time by changing not only their stock of health but also their level of wealth. The time paths reveal the trade-offs that individuals make between current consumption and medical care purchases as well as those between current and future expenditures. The model also provides special insight into the role of risk aversion in determining an individual's response to uncertainty. Our results show that, as intuitively expected, more risk averse individuals will exhibit extra precautionary behavior, especially in the form of additional medical expenditures. Very risk averse individuals may respond to an increase in uncertainty by actually reducing their savings because the increases in medical care are not completely offset by reductions in consumption.

The paper is organized in the following manner. Section 2 presents a stochastic dynamic household production model and the optimization decision. Section 3 describes the dynamic programming procedure used to solve the maximization problem. Section 4 discusses the simulation results and Section 5 concludes the paper.

2. The model

Assume that a retired individual chooses the levels of consumption and medical care that maximize his/her expected lifetime utility subject to wealth and health constraints. She/he solves the following problem:

$$\max_{C_t, M_t} E_0 \sum_{t=1}^{T} \beta^t U(C_t, H_t) \tag{1}$$

subject to

$$W_{t+1} = (1+r)(W_t - C_t - M_t) \tag{2}$$

$$H_{t+1} = \delta H_t + \epsilon_t + (\theta_1 - \theta_2 \epsilon_t) M_t^{\theta_3}$$

$$C_t \geq 0,\ M_t \geq 0,\ H_{t+1} \geq 0, \text{ and } W_{t+1} \geq 0$$

Utility in each time period depends on current consumption, C_t, and health, H_t, and is discounted to the present value at the rate β. Both C_t and H_t must be positive for the individual to survive. Eq. (2) determines the change in wealth when passing from one period to the next. The individual begins time period t with a stock of wealth, W_t, that is diminished by consumption, C_t, and medical care expenditures, M_t, during the period. The remainder of W_t increases with the real interest rate, r, and becomes the level of wealth at the beginning of the next period, W_{t+1}.[1] Individuals have no bequest motive. Consequently, they completely exhaust their wealth during or before time period T, after which they enter an era of their life in which they do not make financial decisions.

Eq. (3) shows the evolution of the stock of health, H_t. It depreciates at the rate $(1-\delta)$, and may decrease due to a non-positive, stationary and exogenous random shock, ϵ_t. The shock could be any illness or injury that causes a large reduction of the stock of health such as a stroke, heart attack, or a hip fracture.

[1] According to our definition of wealth, W_t represents the amount of assets purchased in period $t-1$ plus the interest earned on those assets. Let $\overline{W}_t$ denote the amount of assets purchased in period $t-1$, implying $W_t = \overline{W}_t\ (1+r)$. Substituting this expression into (2) yields $\overline{W}_{t+1} = (1+r)\ \overline{W}_t - C_t - M_t$, which is another common representation of (2).

The stock of health will increase at the end of period t due to expenditures on medical care during t, M_t, made with knowledge of ϵ_t. When $\theta_1 > 0$, $\theta_2 > 0$ and $0 < \theta_3 < 1$, the marginal product of medical care is positive and diminishes as M_t rises. During a time period without a health shock, $\epsilon_t = 0$, the marginal product is lower than during a time period in which a shock occurs, $\epsilon_t < 0$. In addition, the marginal product of medical care increases with size of the shock. [2] Medical care in periods without shocks consists of all purchases that are not in direct response to a current shock. For the elderly this includes preventive care, treatments for common ailments associated with aging such as glaucoma, hypertension or arthritis, and expenditures that increase the stock of health such as care for the remaining effects of past shocks. A health shock causes the demand for medical care to respond to a specific, immediate need. Medical treatment immediately after a stroke, heart attack, broken bone or any acute illness or injury has a high marginal product in this model.

We assume the utility function in each time period takes the following form:

$$U(C_t, H_t) = \frac{\left[C_t^{\gamma} H_t^{1-\gamma}\right]^{1-\sigma} - 1}{1-\sigma}$$

where $\gamma \in (0,1)$. $\sigma > 0$ and helps determine the curvature of the utility function. This utility function is increasing, strictly concave in each argument, and displays a constant degree of relative risk aversion.

In a single argument utility function of the above form, σ is the Arrow–Pratt coefficient of relative risk aversion. Dardanoni (1988) derives the formula for the Arrow–Pratt measure of relative risk aversion for a two-argument utility function. When the arguments of the utility function are consumption and health, and the gamble involves a loss of health, that formula is:

$$R^R = \frac{-H * \partial^2 U / \partial H^2}{\partial U / \partial H}$$

For our utility function, $R^R = \gamma - \sigma(\gamma - 1)$. Since $\gamma \in (0,1)$, the Arrow–Pratt measure of relative risk aversion is positively related to σ. [3] When $\sigma < 1$ the marginal utility from a given consumption expenditure is positively related to health as found in Viscusi and Evans (1990), and a given level of health yields greater utility the higher is consumption, i.e., the cross-partial derivatives with respect to H_t and C_t are positive.

[2] Grossman and Rand (1974) also develop a model incorporating the assumption that the marginal productivity of curative care increases with the degree of illness.

[3] The intertemporal elasticities of substitution with respect to consumption and health are constant and equal to $1/(1-\gamma(1-\sigma))$ and $1/(\gamma - \sigma(\gamma - 1))$, respectively.

3. Solving the model

Although the concave utility function and the quasi-convex constraints yield optimal values for the control variables, the maximization problem presented above does not have a closed form solution. Optimal paths of consumption and medical care expenditures are instead estimated with a numerical simulation procedure suggested by Bertsekas (1976). To implement the simulation, numerical values must be assigned to the parameters of the model and the stochastic process followed by ϵ_t must be defined.

Reasonable, yet arbitrary, parameter values for the simulation are: $T = 15$, $\beta = 1/(1.03)$, $(1 + r) = 1.03$, $\gamma = 0.6$, $\sigma = 0.9$, $\delta = 0.976$, $\theta_1 = 0.75$, $\theta_2 = 0.25$ and $\theta_3 = 0.5$. Fifteen annual time periods are sufficient to follow a 65 yr old to age 80 and are consistent with the Hurd (1989) finding that 90% of the respondents in the Retirement History Survey exhausted their wealth in less than 14.3 yr after age 65. The rate of time preference is set equal to the real rate of return, $\beta = 1/(1 + r)$, to eliminate another reason to save or to dissave.

We select a weighting of utility with respect to consumption, $\gamma = 0.6$, and a $\sigma = 0.9$ for the initial simulations; we later compare these results to those using alternative values of σ. Assuming $\gamma = 0.6$ and $\sigma = 0.9$ implies the index of relative risk aversion, R^R, equals 0.96 in the initial simulation. We know of no existing estimates of our measure of relative risk aversion.

The depreciation rate of health capital increases with a person's age based on a slightly modified version of a formula from Grossman (1972), $\delta = 1 - 0.012 \times \exp(0.021 \times (32 + t))$. Thus, the parameter δ, which is one minus the depreciation rate, ranges from 0.976 at age 65 to 0.968 at age 79. The θ_1, θ_2 and θ_3 values in the health production function allow the marginal product of medical care to be positive, to increase when a health shock occurs, and to diminish with additional increments of medical care. [4]

The stochastic process is driven by the potential health shock, ϵ_t, which takes on a value of zero when the shock does not occur, and a designated negative value representing a loss of health capital when it does occur. We make the transition probabilities of incurring a shock next period inversely related to the current stock of health, H_t, enabling expenditures on preventive care from previous periods to decrease the probability of the incidence of illness in future periods. We also assume the probability of having a shock next period is a positive function of the size of the shock that occurs in the current period. Thus, incurring a shock today increases the probability of a shock next period.

The optimization problem is solved in the following manner, similar to that described by Hubbard et al. (1994). In the final period, T, $M_T = 0$ and $C_T = W_T$.

[4] We do not report our simulations run with different values of γ, δ and the θs. We found that the parameter changes affected the position of the time paths but their shapes and our conclusions about the effects of uncertainty were robust.

For each preceding time period a two-dimensional grid is created. Each grid consists of 150 discrete potential levels of W_t and 150 discrete potential levels of H_t; the levels are scaled from zero to ten. The points represent zero wealth to high wealth and death to extraordinary health for a 65 yr old, respectively. Maximum expected utility is calculated for each of the 22,500 points on the grid in time period $T-1$, given the final period's optimization values, under each of two assumptions: the shock occurs or it does not. [5] Similarly, for each gridpoint in each of the remaining time periods, $t = T-2$ backwards to $t = 1$, optimizing levels of C_t and M_t are computed incorporating the next period's already-calculated optimal choices of C_{t+1} and M_{t+1}. The levels of C_t and M_t for each gridpoint in each time period maximize expected utility, and satisfy the condition that their marginal utilities equal their corresponding discounted marginal utilities in time period $t+1$.

After completing the calculation of the utility associated with each point on the grid in each time period under each of the two assumptions, starting values of W_1 and H_1 are selected for an individual and the optimal C_t and M_t paths determined. Time paths for W_t and H_t are then calculated from the starting values and the C_t and M_t results. These simulated paths, reflecting a variety of starting and parameter values, are shown in the forthcoming figures.

4. Simulation results

4.1. Modelling uncertainty

We use three basic simulations to demonstrate the effects of uncertainty of the incidence of illness. This uncertainty is introduced via the transition probabilities of the occurrence of a shock between time periods. We increase uncertainty by changing the transition probabilities to create first-order and second-order stochastic dominating shifts in the distributions of the random shocks. The new probabilities lead to new optimal paths of medical care and consumption expenditures and stocks of health and wealth. Comparisons of before-shift and after-shift time paths describe the effects of uncertainty. To focus on the effects of the uncertainty of incurring a shock rather than of the shock itself, our simulated patterns do not allow the shocks to occur.

In the first simulation, the transition probabilities for every time period are

[5] Death occurs when $H_t \leq 0.001$. To provide a strong incentive to live rather than to die, a low utility value, $5*[((0.0001)^{1-\sigma}-1)/(1-\sigma)]$, was assigned when $H_t \leq 0.001$. We use $H_t \leq 0.001$ rather than $H_t = 0.0$ because when $\sigma > 1$ and $H_t = 0.0$, utility goes to negative infinity.

$\Pr(\epsilon_{t+1}=0)=1$, eliminating uncertainty of the incidence of illness from the model. In the second simulation the shock takes on the following distribution:

$$\epsilon_{t+1}=\begin{cases}0 \text{ with prob. } (e^{z_t}-1)\big/(1+e^{z_t})\\ -1 \text{ with prob. } 2\big/(1+e^{z_t})\end{cases} \tag{4}$$

where $z_t=1.0+0.2H_t+0.8\epsilon_t$. The third simulation is designed to have the same mean as the second, $-2/(1+e^{z_t})$, but a larger variance. In this simulation the probability of a shock takes on the following distribution:

$$\epsilon_{t+1}=\begin{cases}0 \text{ with prob. } e^{x_t}\big/(1+e^{x_t})\\ -2 \text{ with prob. } 1\big/(1+e^{x_t})\end{cases} \tag{5}$$

where $x_t=1.0+0.2H_t+0.4\epsilon_t$.[6] For the third simulation, the transition probabilities from period one to period two for a person with a medium level of health are 0.9 when moving from ‘no shock in period one to no shock in period two’ and 0.8 when moving from ‘*shock* in period one to no shock in period two’.

Assuming no shock actually occurs, comparing the results of the first simulation with those of the second and third reveals the effects of potentially incurring a shock. The possibility of a shock reduces the expected value of health capital and increases its variance. The potential of a shock also creates a first-order stochastic dominating (FSD) shift of uncertainty; the cumulative distribution function of the occurrence of a shock in the third distribution is always greater than that of the first distribution. An individual with an increasing utility function will always prefer the first distribution. Health-related examples of an FSD shift include the spread of a new, potentially serious virus, a decline in environmental quality, and the effects of aging.

A comparison of the time paths from the second and third simulations demonstrates the effects of a mean-preserving spread, a Rothschild and Stiglitz (1970) increase in risk. A mean-preserving spread represents any situation in which two illnesses/injuries have the same expected loss of health but different severities, perhaps the flu vs. a broken hip for the elderly. Even though the expected health loss is the same, a risk averse individual’s expected utility will be lower when facing the alternative with a higher variance. Thus the certainty equivalent expected value of the second distribution is greater than that of the third, and the risk averse individual will prefer the second distribution.

A change from the second to the third distribution also reflects a second-order stochastic dominating (SSD) shift of uncertainty because the sum of the differ-

[6] The simulations have equal expected values because $x_t=z_t$ with or without the occurrence of the shock.

Table 1

	F_3	F_2	$F_3 - F_2$	$\Sigma(F_3 - F_2)$
-2	$\frac{1}{1+e^{x_t}}$	0	$\frac{1}{1+e^{x_t}}$	$\frac{1}{1+e^{x_t}}$
-1	$\frac{1}{1+e^{x_t}}$	$\frac{2}{1+e^{x_t}}$	$\frac{-1}{1+e^{x_t}}$	0
0	1	1	0	0

ences between the two cumulative probability distributions is greater than or equal to zero for all values of ϵ_{t+1}. As is shown in Table 1, the cumulative probability of the occurrence of the shock in the third distribution exceeds that of the second for $\epsilon_{t+1} = -2$; for $\epsilon_{t+1} = -1$ the cumulative probability of the second distribution is greater than that of the third. However, the sum of the differences of the cumulative distributions equals zero when $\epsilon_{t+1} = -1$. Therefore, the second is less risky and dominates the third in the sense of second-order stochastic dominance.

4.2. Dynamics

Fig. 1 shows the dynamics of the variables of the model in the three basic simulations when no shock occurs. The paths depict the behavior of a maximizing individual who smooths his/her expected utility over the remaining future time periods. The initial values of the state variables, $W_1 = 6$ and $H_1 = 6$, represent medium levels of wealth and health, and the relative risk aversion level is set to that associated with $\sigma = 0.9$.

The ‘certainty’ simulation results are marked with dashed lines in Fig. 1. With certain knowledge of health and wealth, the rational decision-maker will smooth utility through time by selecting reasonably steady levels of C_t and H_t. This is shown in the pattern of the dashed lines; the individual purchases a small amount of medical care during each of the early periods merely to offset depreciation of the stock of health, then decreases those purchases and lets health depreciate a little. Consumption spending is reasonably steady throughout the profiled years, as is the decline in wealth.

The other two simulations contain the possibility of a health loss due to a shock. When presented with this uncertainty, we expect an individual to behave quite differently than in the ‘certainty’ situation by exhibiting some precautionary behavior. This precautionary behavior can take the form of extra investments in health and/or of additional savings to accumulate wealth. Investing in health as a precaution has several positive features. It reduces the probability of a shock in the future and it provides a cushion against the effects of a health shock. The extra health also increases utility to the individual. A precautionary accumulation of wealth enables more savings to be available for medical care after a shock, when medical care is more productive. However, increasing savings implies a reduction

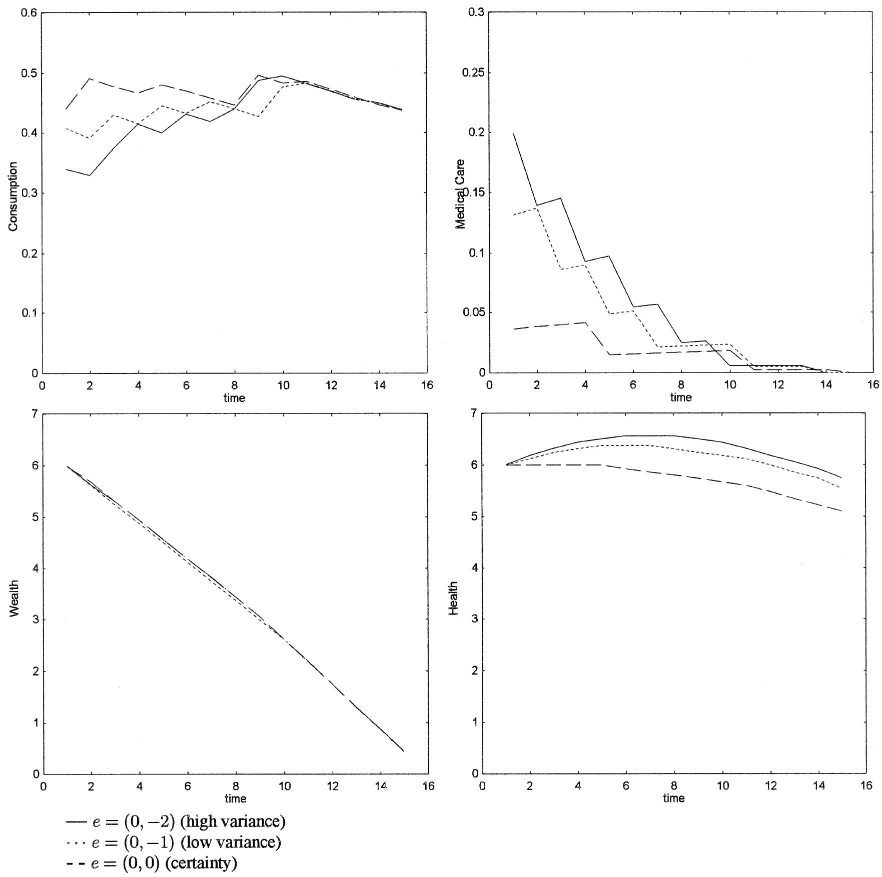

Fig. 1. Three basic simulations for $\sigma = 0.9$.

in utility from the foregone current consumption or expenditure on medical care that would have added to the stock of next period's health. [7]

The solid lines in Fig. 1 are values from the third simulation, run with the potential of a large negative health shock, $\epsilon_{t+1} = -2$, in each time period. They indicate that the individual makes large investments in medical care during the early periods and builds his/her stock of health because of the potential of having a shock. In the periods of high medical expenditures, consumption spending is lower than in the 'certainty' case. As time passes and health shocks do not occur,

[7] In the life-cycle literature, researchers explain, in part, the slow rate of dissaving by the elderly as precautionary behavior against a health shock. We show that when individuals are allowed to spend income on preventive care, this precautionary saving effect will be smaller.

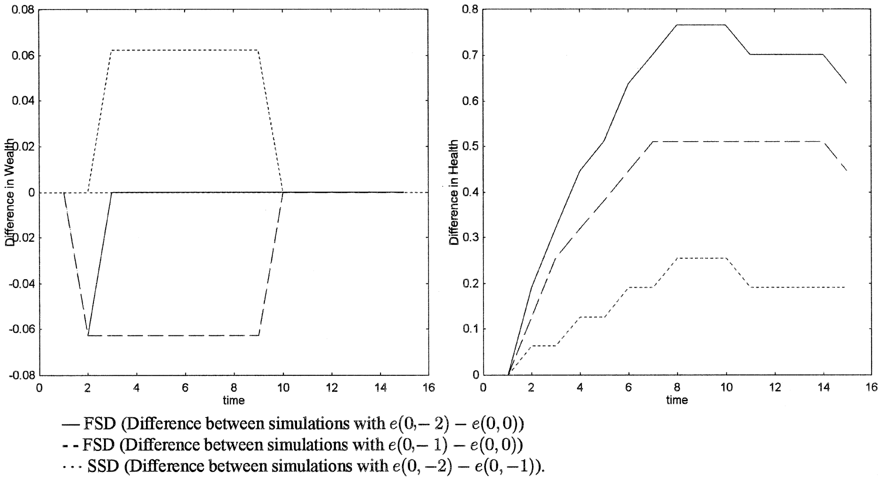

Fig. 2. FSD and SSD effects for $\sigma = 0.9$.

the individual's medical care expenditures continue to fall and his/her consumption spending rises. The dotted lines in Fig. 1 show results from the second simulation, in which the health shock could take on the values of 0 or -1. The spending patterns on medical and consumption are the same as in the $e(0, -2)$ simulation, but the effects of uncertainty are smaller. [8]

To assess the effect of shifts of uncertainty on the accumulation of health capital and wealth, in Section 4.3 we compare the time paths from these basic simulations.

4.3. Responses to FSD and SSD shifts of uncertainty

The two graphs in Fig. 2 demonstrate the effects on the individual's wealth and health capital accumulation of the FSD and the SSD shifts. Two lines on each graph, the solid line and the dashed line, are caused by FSD shifts. The solid lines display the difference between the time paths of H_t and of W_t from the $e(0, -2)$ and the 'certainty' simulations. The dashed lines show the distance between the $e(0, -1)$ and the 'certainty' simulation time paths. In both cases the FSD shift of uncertainty causes the individual to purchase medical care and build health capital. The purchase of additional medical care is more pronounced in the earlier time

[8] A comparison of time paths for individuals with different initial levels of wealth (and medium initial health) reveals that consumption and medical care are normal goods. Simulations with different levels of initial health (and medium initial wealth) show decreasing absolute risk aversion to potential health shocks. An individual who already has poor health foregoes a greater amount of consumption and purchases more medical care than does a person in excellent health.

periods due to the higher returns to investments in health. The effect on the individual's wealth accumulation, however, can be positive or negative. His/her reduction in consumption spending during the early time periods may more than offset the large medical care expenditures and create positive wealth accumulation. It is also possible, as is shown in the 'Differences in Wealth' graph, that the individual's foregone consumption is less than the additional medical care spending, and that wealth is reduced in the early time periods by the FSD shifts of uncertainty.

The dotted lines in Fig. 2 are the differences in the time paths between the $e(0, -2)$ and the $e(0, -1)$ simulated results; they reveal the pattern of the precautionary behavior from an SSD shift of uncertainty. Precautionary behavior caused by an FSD shift responds to both the decrease in the expected value of health and its increase in variance. This SSD shift is a mean-preserving spread, so that the individual's precautionary behavior is only due to the greater variance of the $e(0, -2)$ distribution. A risk averse individual will react to this extra variation by engaging in additional precautionary behavior. In this instance the individual responds to the SSD shift of uncertainty by purchasing more medical care to increase his/her health. The reduction in consumption more than offsets these medical care expenditures and adds a small amount of extra wealth.

From the information in Fig. 2, we see that an increase in health uncertainty in the form of either an FSD or an SSD shift will imply a positive accumulation of health capital, especially during early time periods. The effect on wealth is much smaller in this example and its sign is undetermined. Therefore, when an individual considers the spread of a new disease (an FSD shift) or the possibility of a disease with an equal expected health loss but greater potential reduction of health (an SSD shift), she/he will purchase more medical care, even without contracting a disease. This effect will be stronger the longer is the individual's life expectancy.

Although an individual with an increasing utility function will exhibit precautionary behavior when facing an FSD shift of uncertainty, only risk averse individuals display precautionary behavior from a mean-preserving spread (our SSD shift). In Section 4.4 we explore the sensitivity of precautionary behavior to an individual's degree of risk aversion.

4.4. Risk aversion and the effect of uncertainty

Consider three individuals, identical except for their degrees of risk aversion, facing the SSD shift of uncertainty from Section 4.3, moving from the $e(0, -1)$ to the $e(0, -2)$ probability distribution of a shock. We expect each individual will respond with additional precautionary behavior. The amount of extra precautionary behavior should be correlated with the individual's level of risk aversion.

Fig. 3 contains the simulation results that we will use to calculate the effect of an SSD shift of uncertainty on the stock of health and wealth for these three

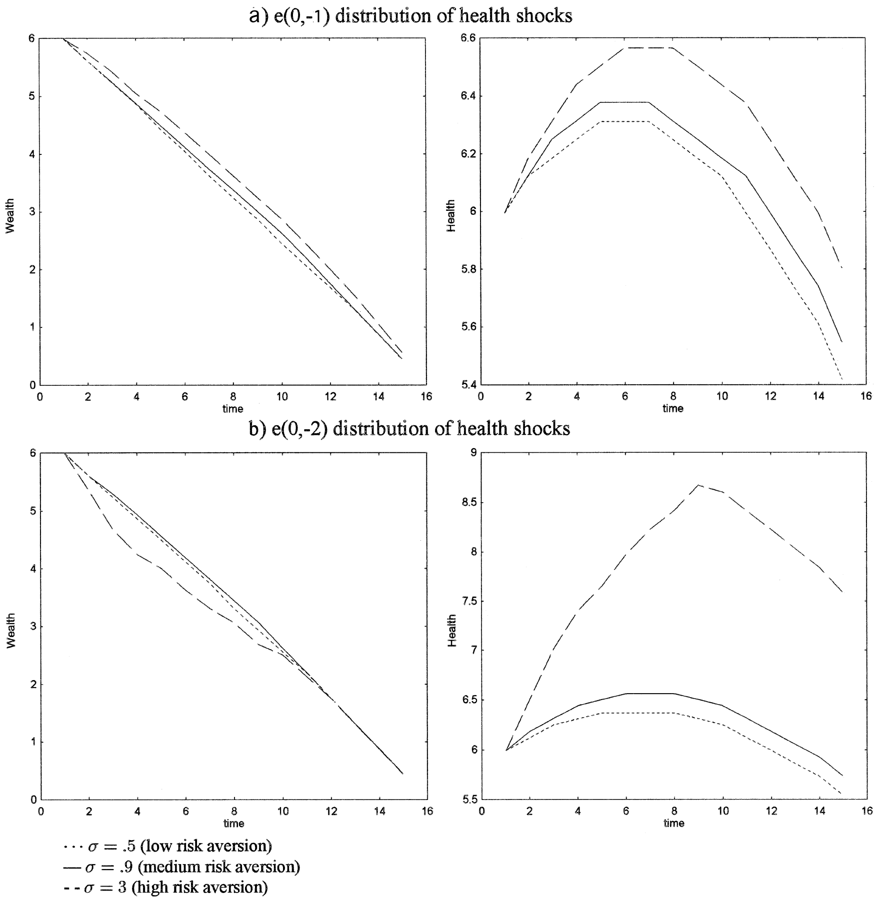

Fig. 3. Three degrees of risk aversion.

individuals. The starting values are again $H_1 = W_1 = 6$. The top two graphs reflect behavior when the individuals are subject to the $e(0,-1)$ distribution and the second row of graphs when they face the $e(0,-2)$ distribution of health shocks. The right diagrams show that the individual's precautionary accumulation of health capital is positively correlated with his/her degree of risk aversion for each of the distributions of the health shock. The left two diagrams, however, reveal the absence of a monotonic relationship between the accumulation of wealth and risk aversion.

As in Section 4.3, a change in decision-making from the $e(0,-1)$ distribution to the $e(0,-2)$ distribution comprises a mean-preserving spread. The change in behavior due to this SSD shift of uncertainty for each of the three individuals can

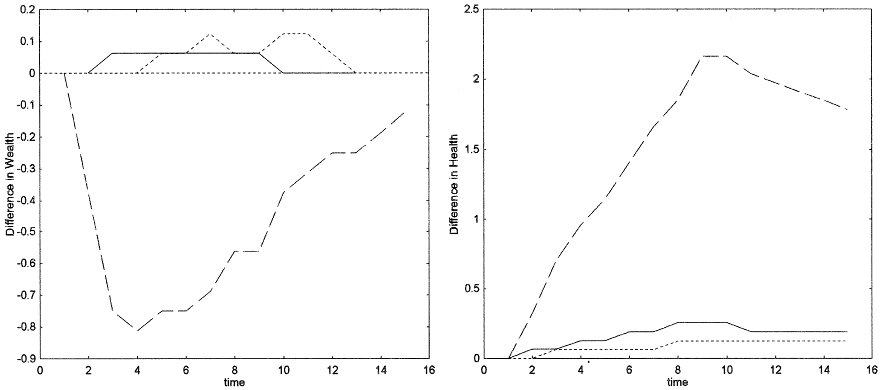

Fig. 4. Effects of risk aversion on SSD shifts.

be calculated by subtracting the time paths in the first row of graphs from those in the second row. The result of the subtraction is Fig. 4.

An individual's precautionary response to the SSD shift could take a variety of forms. For example, the most risk averse individual may increase his/her purchases of medical care more than those with less risk aversion and may build up an even larger increment of wealth during the early time periods. Alternatively, the highly risk averse person may already be spending such a high proportion of his/her wealth on medical care due to the initial uncertainty that the SSD shift will only cause a small addition to medical care expenditures. A less risk averse person, who was not spending as much on medical care initially, may be able to afford a larger increase in medical care expenditures in response to the additional uncertainty. [9]

In Fig. 4 our very risk averse individual builds his/her stock of health by reducing wealth to pay the large medical expenditures. The other two individuals react to the extra uncertainty by making modest increases in their wealth and health; the least risk averse individual adds a smaller amount of each.

From Figs. 3 and 4 we see that greater risk aversion causes extra precautionary behavior in an uncertain environment even when a health shock does not occur. Increases in medical care expenditures due to the SSD shift of uncertainty are directly related to the degree of risk aversion. The accumulation of wealth as a precautionary behavior can be positively or negatively related to risk aversion. The negative effect on wealth accumulation occurs when the desire for extra health is

[9] Although not shown in the graphs in this paper, we find this behavior for individuals with low initial values of health and wealth.

so strong that medical expenditures are financed by both foregoing consumption and reducing savings.

5. Conclusion

In this paper we examine the effect of uncertainty of a shock to the stock of health during a person's retirement years. We derive time paths of consumption, medical care expenditures, health capital and wealth by solving a dynamic household production model by numerical simulation. In doing so we expand the ability to describe the effect of uncertainty on the demand for medical care from a signed, or an unsigned, term in a comparative static solution to a pattern of precautionary behavior based on a series of optimizing decisions. These patterns allow us to better understand the interactions between an individual's spending on medical care and consumption and his/her decision to accumulate health capital and/or wealth.

Confronted by uncertainty, elderly individuals will exhibit precautionary behavior to smooth their expected utility across time periods. The pattern of precautionary behavior will take the form of additional medical care expenditures and reduced consumption in the early time periods. The stock of health capital will always increase with increments in uncertainty. The effect is greater, the longer the person's life expectancy. The effect of uncertainty on savings can be positive or negative. Savings will be positive (negative) when the amount of foregone consumption is greater (less) than the additional medical care expenditures. The increments to the stock of health are correlated with the individual's degree of relative risk aversion because a more risk averse individual experiences a greater reduction in his/her expected utility due to a given increase in uncertainty.

The model developed in this paper can also be helpful in analyzing other healthcare topics. For example, we could use this model to study the demand for medical care in an uncertain environment, obtaining comparative dynamics from parameter changes and deriving testable hypotheses. Alternatively, we could modify our health production function to examine the trade-off between preventive and curative care. The objective would be to extend the work of Grossman and Rand (1974), who investigate this trade-off in a model that, similar to that in this paper, allows the marginal product of medical care to increase with the degree of illness. Preventive care would lower the probability of a health loss, as Grossman and Rand suggest, and all decision-making would be in an uncertain environment. Finally, in the life-cycle consumption literature it is common to compare the simulated patterns of savings with actual data. We could also use the model to compare simulated patterns of precautionary behavior with sample data. To do this, we would need data over time on savings and detailed information about medical care expenditures and health status.

Acknowledgements

The authors would like to thank Frank Sloan, Stephanie Schmitt-Grohé, participants of the USF departmental workshop, and an anonymous referee for their comments. We are responsible for any remaining errors. The first author acknowledges support from the University of South Florida Institute on Aging Pilot Research Grant Program. This paper represents the views of the authors and should not be interpreted as reflecting the views of the Board of Governors of the Federal Reserve System or other members of its staff.

References

Arrow, K., 1963. Uncertainty and the Welfare Economics of Medical Care. Am. Econ. Rev. 53, 941–973.

Bertsekas, D., 1976. Dynamic Programming and Stochastic Control. Academic Press, New York.

Chang, F., 1996. Uncertainty and investment in health. J. Health Econ. 15, 369–376.

Dardanoni, V., 1988. Optimal choices under uncertainty: the case of two-argument utility functions. Econ. J. 98, 429–450.

Dardanoni, V., Wagstaff, A., 1987. Uncertainty, inequalities in health and the demand for health. J. Health Econ. 6, 283–290.

Dardanoni, V., Wagstaff, A., 1990. Uncertainty and the demand for medical care. J. Health Econ. 9, 23–38.

Grossman, M., 1972. The Demand for Health: A Theoretical and Empirical Investigation. National Bureau of Economic Research, New York.

Grossman, M., Rand, E., 1974. Consumer incentives for health services in chronic illness. In: Mushkin, S.J. (Ed.), Consumer Incentives for Health Care. Milbank Memorial Fund, New York, pp. 114–151.

Hubbard, R., Skinner, J., Zeldes, S., 1994. The importance of precautionary motives in explaining individual and aggregate saving. Carnegie-Rochester Conference Series on Public Policy, 40, 1994, pp. 59-125.

Hurd, M., 1989. Mortality risk and bequests. Econometrica 57, 779–813.

Rothschild, M., Stiglitz, J., 1970. Increasing risk: I. A definition. J. Econ. Theory 2, 225–243.

Selden, T., 1993. Uncertainty and health care spending by the poor: the health capital model revisited. J. Health Econ. 12, 109–115.

Viscusi, W., Evans, W., 1990. Utility functions that depend on health status: estimates and economic implications. Am. Econ. Rev. 3 (81), 353–374.