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Behavioral Simulations

Using agent-based modeling to understand policyholder behaviors

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Editors' Note: This is part one of a two-part series on behavioral simulations.

Introduction

Understanding past policyholder behavior and making assumptions about how current and future policyholders are likely to behave in the future are critical to the insurance industry. Policyholder behavior in terms of purchase behavior (e.g., the type of guarantees or riders purchased), withdrawal behavior (e.g., partial or full withdrawal, when and for what reasons), surrender or lapse behavior, and option exercise behavior (e.g., the decision to annuitize or not annuitize or the exercise of long-term-care rider within an annuity contract) are all essential in determining how to (a) market insurance products, (b) price products and evaluate product profitability, (c) compensate agents and advisors for acquisition and retention of policyholders, (d) value assets, liabilities, reserve and capital for various economic conditions, and (e) transfer or hedge the risks.

Insurance professionals have used a number of mathematical, statistical, financial and economic theories to understand policyholder behavior and quantify future liabilities and risks. Assumptions about future policyholder behavior form a key aspect of insurers' pricing, reserving, and hedging strategies and policies. Earlier attempts at modeling policyholder behavior have taken deterministic (or closed-form solutions) or stochastic approaches of modeling the base and dynamic behavior of policyholders. Such approaches suffer from two major drawbacks:

- 1. Aggregate Level Modeling:** The approaches have been at an aggregate level with little or no differentiation of policyholder behavior based on different socio-demographic, attitudinal or behavioral factors. Such an aggregate level analysis fails to account for the value that different policyholders place on certain features (e.g., number and type of fund choices available within a life insurance policy or annuity contract, liquidity versus guarantees).
- 2. Rational Approach:** The approaches have assumed a classical rational expectations approach, and do not account for how strongly social, cognitive and emotional factors influence consumers' financial decisions. For example, policyholder decisions around lapses or surrender may not be based on in-the-moneyness (ITM)

of an option, but may be driven by loss aversion, job insecurity and the need for liquidity.

Recently, insurance professionals have begun to address these two issues by embracing behavioral economics and predictive modeling.

Behavioral Economics: Behavioral economics is the study of actual (as opposed to rational) decision making by consumers and takes into account their social, cognitive and emotional biases. In addition, behavioral economics provides insights into changing policyholder behaviors by "nudging" policyholders to make decisions that are beneficial to them and the system overall. The Society of Actuaries (SOA) has conducted workshops and published papers that demonstrate the application of behavioral economics in analyzing retirement savings, modeling lapse rates in insurance products, projecting when policyholders might exercise options, and determining how customers react to changing economic patterns. These analyses have uncovered the underlying behavioral principles such as bounded rationality and willpower driving decision making. For example, risk-averse consumers should place a higher value on annuities with minimum guarantees that provide income for life because they offer protection against longevity and equity risk. However, it is well known that pre-retirees and retirees fail to annuitize any lump-sum savings, either in full or partially. This is often referred to as the *annuity puzzle*.

Predictive Modeling: According to the SOA Predictive Modeling Survey Subcommittee, upwards of 40 percent of survey respondents are using or considering using predictive modeling to better understand policyholder behavior. Predictive modeling uses statistical techniques to understand the interactions between many factors that influence a policyholder's decisions. For example, predictive modeling can help insurers determine the interaction between income and age, and the impact it has on lapse rates. This is more powerful than traditional techniques that commonly account for very few variables when modeling policyholder behavior, and do not typically account for the interaction effects of those variables.



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While significant advances are being made in the use of behavioral economics and predictive modeling in understanding policyholder behavior, we see two fundamental challenges:

1. Modeling individual policyholder behaviors:

Behavioral economics describes a number of shortcuts or decision rules that people use when making decisions under limited and uncertain information. These decision rules (e.g., use of defaults, hyperbolic discounting, endowment principle, etc.) are often used to explain policyholder decisions discussed earlier. However, using these decision rules to consistently model and evaluate impact on insurer assets and liabilities requires us to move away from an aggregate level model to an individual consumer or policyholder-level model.

2. Modeling causal structure of individual decision making:

While predictive modeling is more effective than traditional techniques in capturing the interaction between multiple variables, it fails to capture the rich structure of causal influences and nonquantitative factors (e.g., the emotional and social factors) that influence policyholder decision making. Furthermore, predictive modeling relies on historical experience to predictive future experience. Thus, it is not very reliable predicting future experience when there is a fundamental change in the environment. Individual software agent-based models, extensively used in artificial intelligence (AI) based systems, can effectively capture the complex causal structure of individual policyholder decision making under diverse environmental conditions.

In this paper, we present a unique approach, called behavioral simulation, which combines individual decision rules and AI-based software agent modeling to model policyholder behavior. Advances in artificial intelligence allow us to simulate behavior at an individual level and then analyze the overall, aggregate outcomes. These models simulate the simultaneous operations and interactions of multiple individuals to recreate a system and predict complex phenomena. This process results in

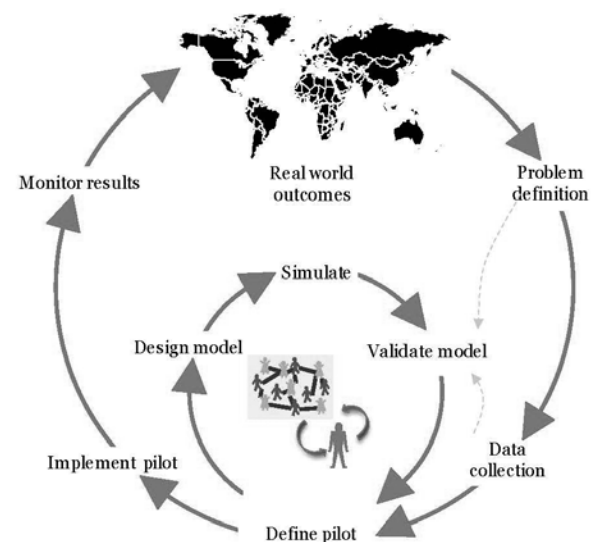
emergent behavior at the macro level based on micro-level system interactions. The concept is that the simple behavioral rules that define the simulated individuals' actions generate complex behavior at the macro level. The behavioral rules for each individual are based on the segment-specific behavioral economic principles informed by the consumer data.

This approach is applicable for modeling a variety of purchasing, withdrawal, lapse or surrender, and option exercise behaviors. Simulation models are beginning to play a central role in the design, distribution and risk management of insurance products. They promote a more sophisticated understanding and evaluation of product design, pricing, valuation, reserving and hedging. In this paper, we describe the specific application of this method to modeling withdrawal and lapse behavior of variable annuity policyholders.

Agent-Based Modeling Background

Software agent-based modeling simulates agents' (e.g., individuals' and companies') interactions with their environment and other agents in order to understand the emergent behavior of complex systems.¹

Exhibit 1: Agent-Based Models

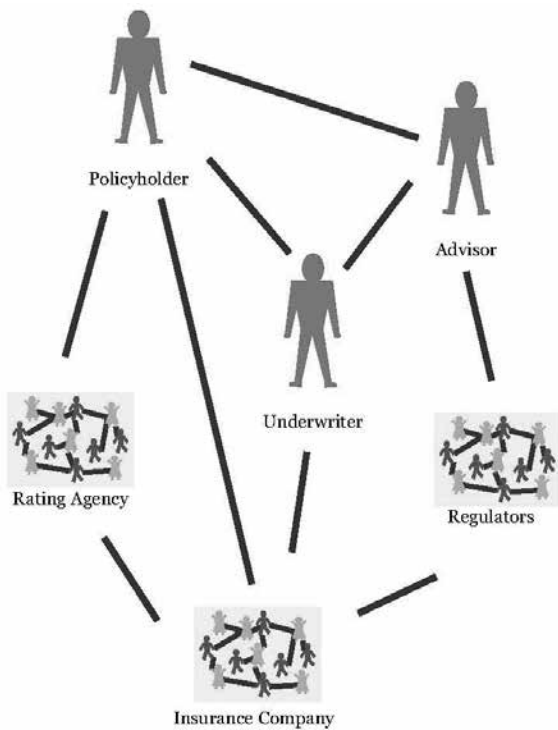


A striking feature about these models is they can be designed to “learn” as more data become available. Initially, certain assumptions will be made about how environmental factors will affect the behaviors of various agents and how they interact with the environment and with other agents. Then, as certain behaviors emerge in response to changes in the environment and interactions with other agents, these assumptions will be refined to more accurately capture and understand this emerging behavior.

Key Concepts

Anyone or anything that makes decisions can be viewed as an agent. For example, policyholders, financial advisors and insurance underwriters can be modeled as agents. The same is true for insurance companies, regulators and rating agencies.

Exhibit 2: Examples of Agents



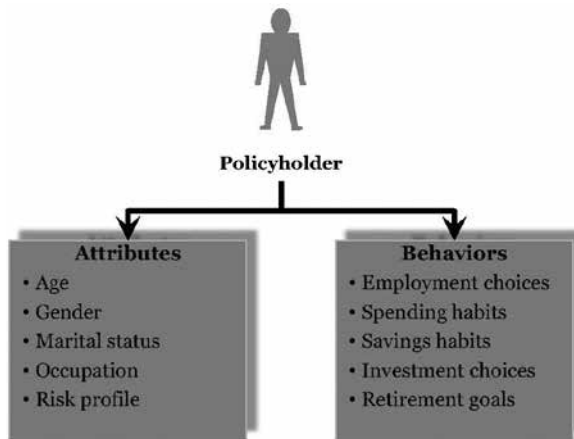
Agents are the central building blocks of an agent-based model. They:

1. Receive information from their environment and from other agents,
2. Process that information, and
3. Act on that information.

In many instances, agents will adapt or learn as they react to changes in the environment. Conversely, the actions of agents may cause the environment to change. These interactions result in a complex, dynamically changing system.

In an agent-based model, each agent has a set of attributes and behaviors. The combinations of attributes like age, gender, marital status, occupation and risk profile uniquely identify the agent.

Exhibit 3: Defining an Agent



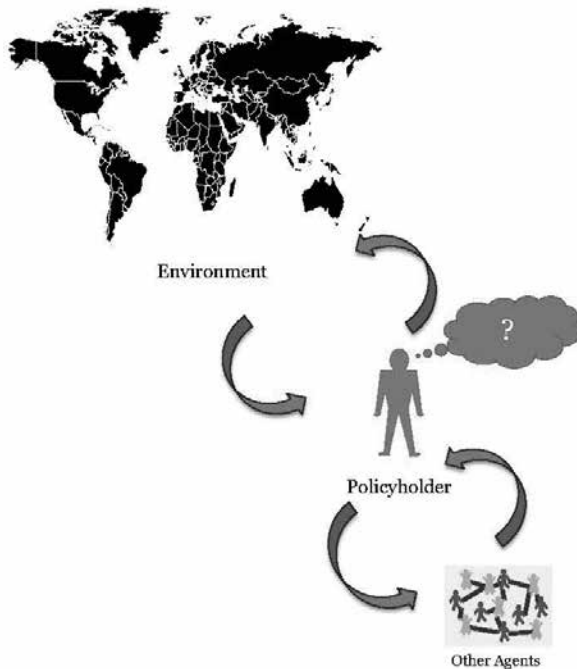
The behaviors are a set of rules that define how the agent will react to changes in its environment and to interactions with other agents. For example, a policyholder’s actions with regards to employment choices, spending habits, savings habits, investment choices and retirement goals will be strongly influenced by his life situation and the state of the economy.

The behaviors define an agent’s “personality” and are usually governed by the following decision process. First, the agents assess the current environment and

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decide on a course of action. Second, the agents perform the chosen action. Third, agents evaluate the results of their actions and adjust their behavior accordingly.

Exhibit 4: Agent Behaviors



For example, consider a policyholder who is retired and owns a 30-year U.S Treasury bond with a 12 percent coupon rate that is about to mature. She discusses with friends what she should do with the proceeds when this bond matures. Given the current low interest environment and the advice she receives, she chooses to invest in a one-year certificate of deposit and to cut back on discretionary expenses to compensate for the loss of income. Each year, she will reassess this decision. Among other considerations, this reassessment will take into account the advice from others, the level of interest rates, her spending needs and her wealth.

In our behavioral simulation approach, the retired policyholder is modeled as a “software agent.” This agent contains attributes of the specific policyholder (e.g., their age, gender, occupation, the asset holdings and their maturity dates). This agent communicates and can share information with other agents (e.g., receive advice from

friends, consult an insurance agent) to make decisions about her portfolio (e.g., reinvest, withdraw).

Environment

There are numerous environmental factors that influence a policyholder’s behavior. This paper will focus on two environmental influences:

1. Where the policyholder is in his life cycle; and
2. The current state of the economy.

These two environmental factors have a significant influence on behaviors. In fact, they probably are the most important environmental variables that substantially influence policyholder behavior. This is not to say that other environmental factors are not important. The restriction to these two environmental factors puts a reasonable limit on the scope of this paper without sacrificing realism.

A natural extension of the focus of this paper is modeling:

- Interaction of policyholders with their advisors;
- Changes in government social programs such as Social Security and Medicare; and
- Changes in the tax system.

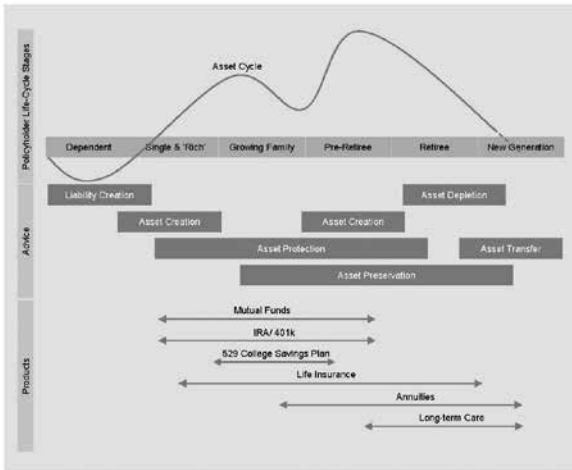
Other natural extensions are modeling how various agents behave under extreme environmental conditions. One example is modeling the behaviors of retired policyholders if the current low interest rate environment continues for a prolonged period of time; conversely, modeling what would be the impact on this same cohort if there is a sudden shift to very high interest rates and inflation. This type of agent-based stress testing will facilitate more comprehensive product design and risk management.

There are many other environmental factors that can be explored using the techniques discussed in this paper.

Life Cycle

At the model’s start date, the policyholder is placed in a particular life situation as per his age, marital status and other attributes. As he ages, he will progress through various stages.

Exhibit 5: Life Cycle



As shown in the above exhibit, the life cycle of a policyholder will be divided into six stages:

1. Dependent
2. Single & “Rich”
3. Growing Family
4. Pre-Retiree
5. Retiree
6. New Generation

“New Generation” refers to the heirs who inherit the remaining assets.

The current life stage of the policyholder affects the type of advice he will seek from other agents and the types of investment and insurance products he will purchase, such as mutual funds, retirement accounts, college savings plans, life insurance, annuities and long-term care.

Where the policyholder is in his life cycle will also affect his behavior on managing his standard of living, wealth and health. Specifically, it will affect behaviors with regard to:

1. Income sources
2. Spending habits
3. Savings rate
4. Asset allocations
5. Risk profile

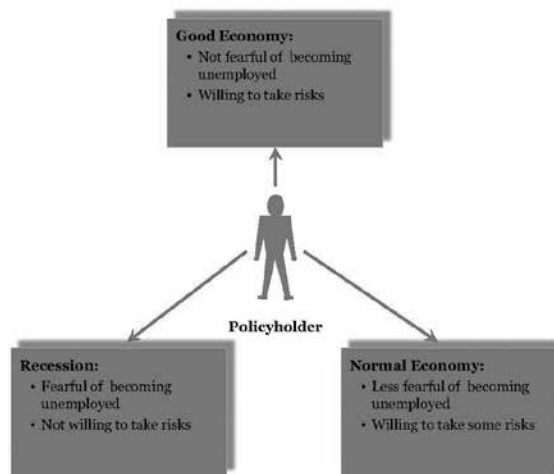
For example, a 30-year-old female who is married, has two children and is working full time will behave very

differently than a 75-year-old female who is retired, has a few health issues and is living on Social Security and a small pension.

Economic

The behavior of individuals will be strongly influenced by their cognitive, emotional and social status, as well as the state of the economy. For example, in a good economy, policyholders are generally not fearful of becoming unemployed and are willing to take risks. Conversely, in a recession, policyholders are generally less confident about their employment situation and are less willing to take risks.

Exhibit 6: Economic Environment



Similar to the life cycle of the policyholder, the state of the economy will affect:

1. Income sources
2. Spending habits
3. Savings rate
4. Asset allocations
5. Risk profile

Of particular interest will be the effect that the state of the economy has on the decision-making process the policyholder goes through when tapping his investments to provide for shortfalls in the income sources (e.g., salary, Social Security and pension).

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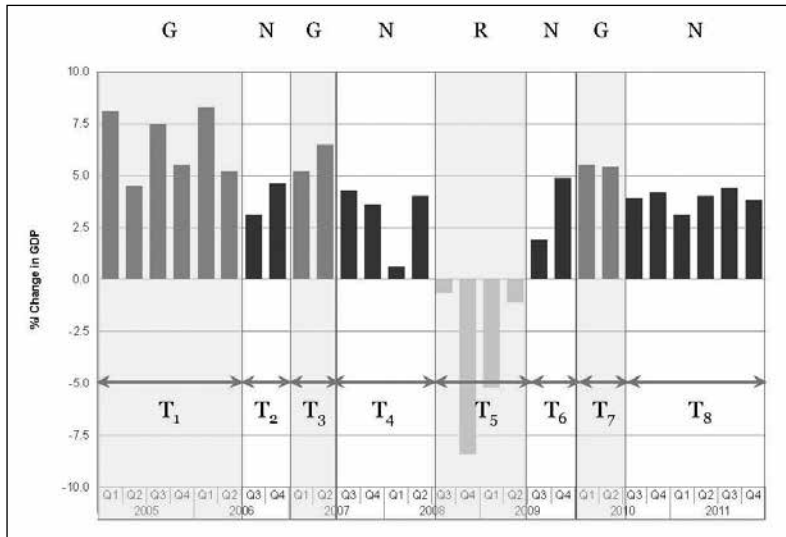
Regimes

A regime-switching framework will be used to simulate the behavior of individuals in three different economic states or regimes:

1. Good economy
2. Normal economy
3. Recession

This paper defines these states using the percentage change in the real gross domestic product. The economy is in a good state when the real gross domestic product is growing at a rate greater than 5 percent. The economy is in a normal state when the real gross domestic product is growing at a rate between 0 percent and 5 percent. Finally, the economy is in a recessionary state when the real gross domestic product is contracting (i.e., the grow rate is less than 0 percent).²

Exhibit 7: Waiting Periods



The random variable $T_{i|r}$ will denote how long the economy is in a particular state. Algebraically,

$$T_{i|r} \sim \text{Exponential}(\lambda_r)$$

Where,

$T_{i|r}$ = number of time periods before the i^{th} switch given the r^{th} regime; and

λ_r = expected waiting time given the r^{th} regime.

Using the quarterly percentage (%) change in the real gross domestic product from the first quarter of 1954 through the first quarter of 2012, the following exhibit shows the average waiting time for each state of the economy.

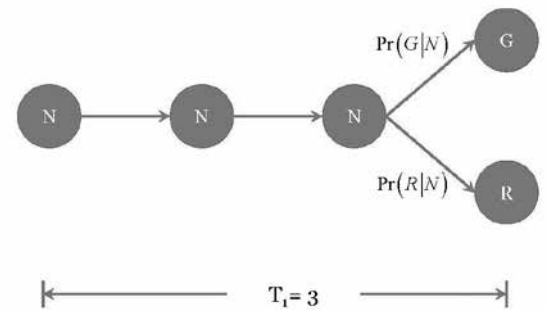
Exhibit 8: Average Waiting Times

State	Average Time
Good	2 Quarters
Normal	3 Quarters
Recession	1 Quarter

Transitions

At the end of the waiting period, the economy will switch to a different state. For example, if the economy is currently in a normal state and the end of the waiting period is reached, then it will switch to either a good economy or a recession.

Exhibit 9: Transitions



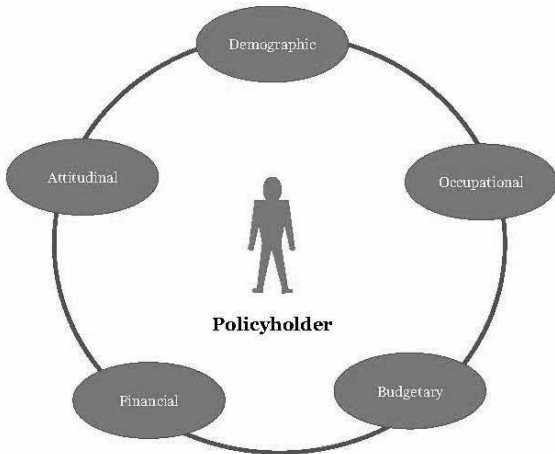
Returning again to the quarterly percentage change in the real gross domestic product from the first quarter of 1954 through the first quarter of 2012, the following exhibit shows the transition probabilities from one state of the economy to another state.

Agents

Attributes

Attributes uniquely identify the policyholder. Five categories of attributes will be used to identify a policyholder:

1. Demographic
2. Occupational
3. Budgetary
4. Financial
5. Attitudinal.



Demographic attributes include the following about the policyholder:

1. Age
2. Gender
3. Marital status.

These attributes will be used for a variety of purposes such as where they are in the life cycle, spending needs, likelihood of needing medical care, and likelihood of dying.

Occupational attributes include the following about the policyholder:

1. Employment status
2. Occupation
3. Income

These attributes will be used to determine policyholders' major source of their income, their likelihood of becoming unemployed, and the timing of their retirement.

Correlated with the demographic and occupational attributes, the budgetary attributes identify their spending habits. Their spending habits will be classified into three categories:

1. Nondiscretionary expenses
2. Discretionary expenses
3. Health care expenses

Nondiscretionary expenses are expenses that the policyholder has limited control over, including costs for food, clothing and shelter. Discretionary expenses are expenses that the policyholder does have control over, including costs for travel, hobbies and charitable donations.

Also correlated with the demographic and occupational attributes, the financial attributes identify the level and type of financial assets they are likely to own. Specifically, the net worth of the policyholder will be allocated among five asset classes:³

1. Savings (i.e., checking, money market)
2. Certificates of deposit (CDs)
3. Mutual funds
4. Variable annuities
5. 401(k), 403(b) and individual retirement accounts (IRAs)

A policyholder will not necessarily own all five of these asset classes. Ownership will depend on several attributes such as age, income and net worth.

Attitudinal attributes describe the policyholder's attitude toward risk (i.e., risk profile). A policyholder's attitude toward risk will fall into one of three risk profiles:

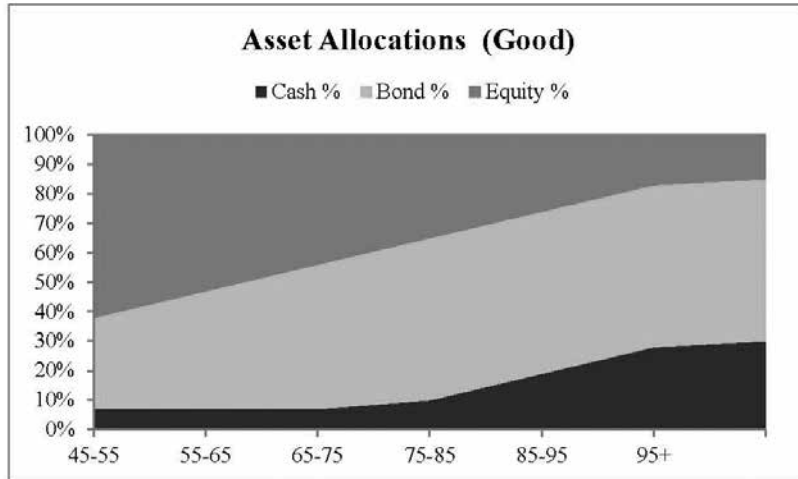
1. Conservative
2. Moderate
3. Aggressive

These risk profiles will be used to allocate the assets within mutual funds, 401(k) and variable annuities among equities, bonds and cash.

The allocation to equities, bonds and cash will change as the policyholder progresses through the life cycle. For example, the following exhibit shows the investment allocations of a policyholder with a moderate risk profile when the economy is in a good state.

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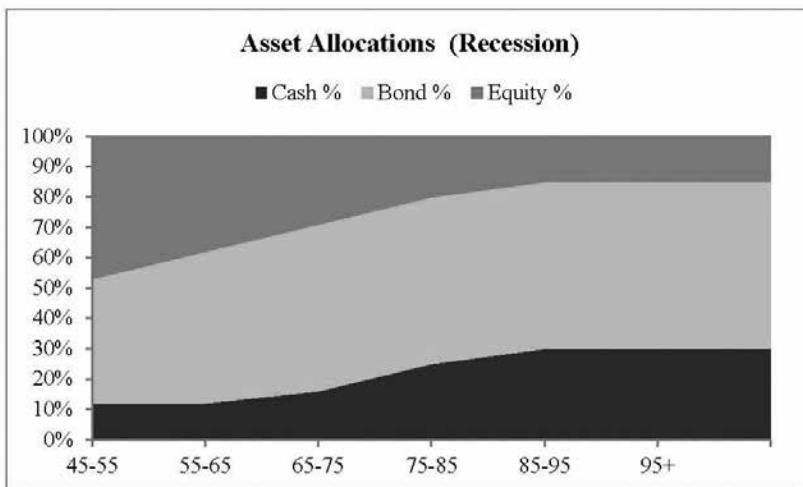
Exhibit 11: Investment Allocations During a Good Economy



Allocations to bonds and cash increase as this policyholder ages. For example, at age 50, approximately 60 percent of his portfolio is in equities, 30 percent in bonds and 10 percent in cash; whereas, starting at age 95, approximately 20 percent is in equities, 60 percent in bonds and 20 percent in cash.

Similarly, the allocation to equities, bonds and cash will change when the economy switches states. For example, the following exhibit shows the investment allocations of a policyholder with a moderate risk profile when the economy is in a recessionary state.

Exhibit 12: Investment Allocations During a Recession



For example, in the previous exhibit, where the economy is in a good state, a 50 year-old policyholder with a moderate risk profile has approximately 60 percent of his portfolio invested in equities, 30 percent in bonds and 10 percent in cash. In contrast, when the economy is in a recession, this same policyholder is expected to have approximately 45 percent invested in equities, 40 percent in bonds and 15 percent in cash.

Behaviors

With policyholders as the primary focus, it is essential that not only are their attributes accurately specified, but also that their behaviors are properly identified.

Multiple behaviors can be captured by behavioral simulations. However, for purposes of this paper, the two behaviors of policyholders that will be observed closely are their employment choices and withdrawal choices. Specifically, a behavior that will be modeled is when the policyholder chooses to:

1. Retire; or
2. Return to work, if he is currently retired

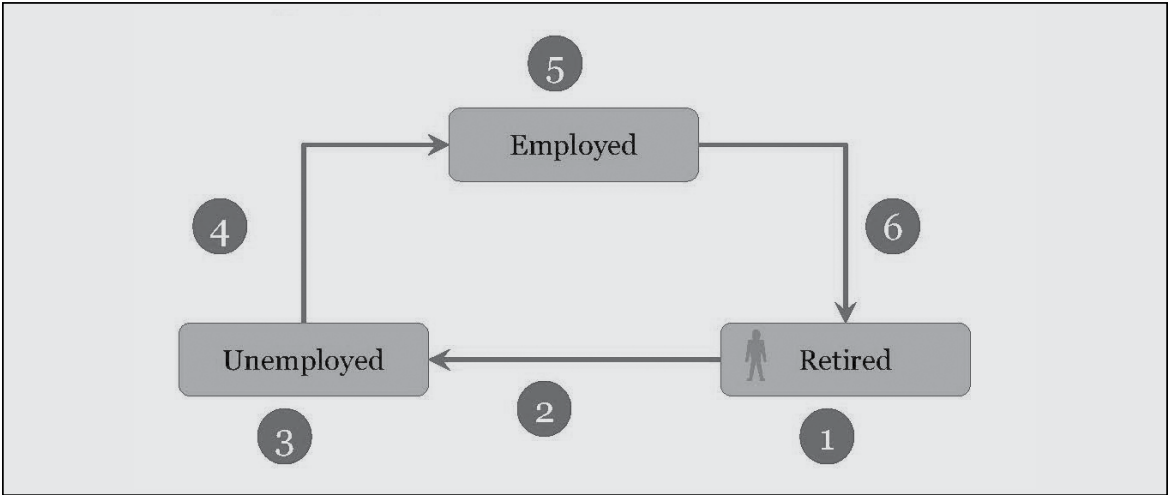
Another behavior that will be the observed closely is when the policyholder decides to utilize his variable annuity contract to:

1. Make a partial withdrawal;
2. Surrender his contract (i.e., make a full withdrawal); or
3. Do nothing

Employment Status

Using the various attributes of the policyholder such as the age, occupation, and income and unemployment rates, the model simulates the employment status of the policyholder—actively at work, seeking employment or retired.

Exhibit 13: Employment Decisions



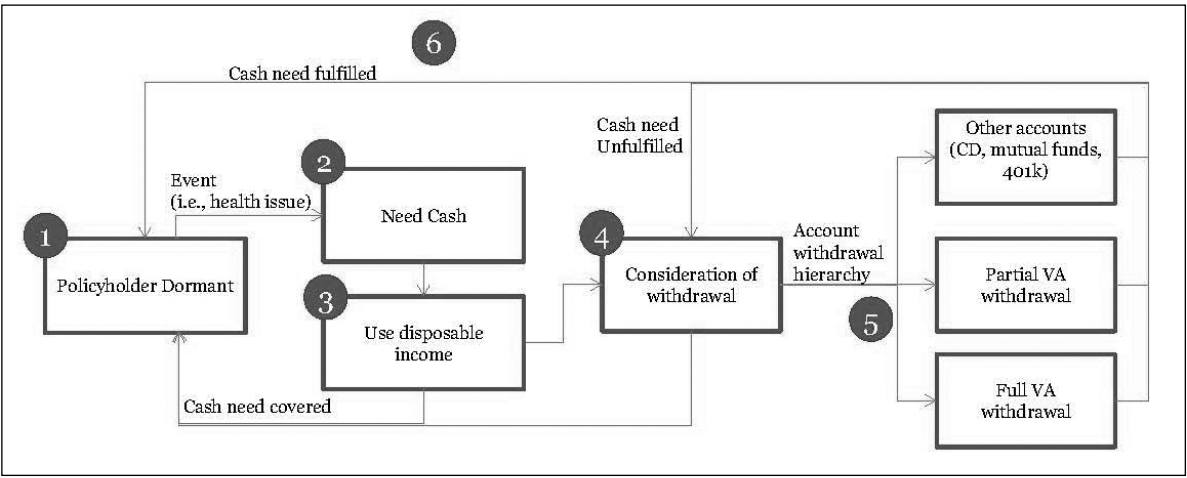
For example, consider a policyholder who just retired but his income barely covers his expenses. If his expenses increase (e.g., because his wife has unexpected health care costs), then he may be forced to look for a job. He will be considered unemployed while he searches for a job to cover his extra expenses. He will then find a new job with a probability based on his age, occupation and the current state of the economy. While he is employed, he will have enough income to cover these new health care costs. Once her illness passes and the health care costs drop or he becomes too ill to work, he will return to retirement.

Cash Fulfillment Needs

When a policyholder’s income sources (e.g., salary, Social Security and pension) exceed his expenditures, he will be considered dormant. In other words, he will not be deciding to make a withdrawal from his investments but instead will be adding money to these investments.

When a policyholder determines that he needs to make a withdrawal from one of his investments, he will be considered active. During this active state, he will determine how much money he needs and from which investment he will make a withdrawal.

Exhibit 14: Withdrawal Decisions



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Continuing with the previous example, the retired policyholder will remain dormant with no financial concerns as long as his income covers his expenses. When his wife gets sick, he will calculate how much money he will need to cover her medical bills. While he is looking for a job to cover her medical bills, he will calculate how long they can live off of their current income sources. If he does not believe his sources of income will cover his expense during the time he is job searching, he will begin to worry and consider withdrawing cash from his investments. If he decides to withdraw, he will follow a “withdrawal hierarchy,” tapping into one account at a time until he has fulfilled his cash need. Once his cash need is fulfilled, he will return to the dormant state.

Withdrawal Hierarchy

When there is a cash need, the policyholder’s decision of whether to make a withdrawal from his variable annuity contract will depend on:

1. What other type of financial assets he owns;
2. What are the tax consequences; and
3. How much the variable annuity contract is “in-the-money”

With regard to the last criteria, consideration will also be given to various contract provisions such as the surrender penalty and whether the guaranteed minimum benefit of the variable annuity contract is still in the waiting period.

Other influences that will affect the policyholder’s withdrawal behavior are:

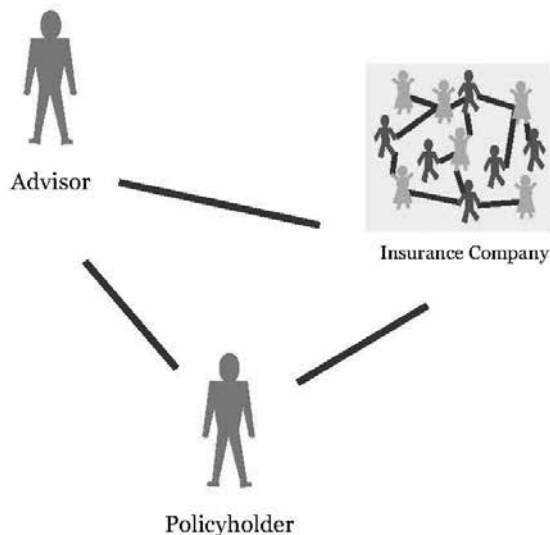
1. The relationships with the advisor and insurance company;
2. The policyholder’s bias;
3. The policyholder’s awareness of the tax implications; and
4. The policyholder’s understanding of the provisions of the variable annuity contract.

In short, policyholders’ decision to withdraw money from their variable annuity contract is not based solely on the moneyness of the contract, but on a variety of factors that more closely reflect real life. □

The opinions expressed and conclusions reached by the authors are their own and do not represent any official position or opinion of the Society of Actuaries or its members. The Society of Actuaries makes no representation or warranty to the accuracy of the information.

¹ The word “agent” in this paper refers to a “software agent” or a computer process that encapsulates the decision making of individuals, companies, etc. It does not refer to an “insurance agent.”
² This definition of recession is different from the official definition, which is two successive quarterly contractions.
³ The primary residence of the policyholder will be ignored.

Exhibit 15: Influences of Other Agents



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