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# White, Gray and Black Swans

## IDENTIFYING, FORECASTING AND MANAGING MEDICAL EXPENDITURE TREND DRIVERS IN A COMPLEX WORLD

*By Alan Mills*

Many of us assume that current actuarial methods for identifying, forecasting and managing medical expenditure trend drivers are effective and adequate. But this assumption may be mistaken: Just as economists and Wall Street quants (quantitative analysts) were recently shocked to discover that their methods were inadequate to avoid dramatic upheaval in highly complex financial systems, our actuarial methods may be inadequate for equally complex healthcare systems. This paper explores how health care complexity challenges us to expand our repertoire of actuarial methods—and even recast our trend driver paradigm—in order to do our jobs better and maintain our credibility.

### HEALTH CARE COMPLEXITY

Advanced health care systems, such as those in the United States and Canada, are examples of so-called complex adaptive systems (CAS), a fact that has profound implications for actuarial work. For more than 30 years, eminent scientists have studied CAS at research centers such as the Center for Complex Systems at the University of Michigan, the New England Complex Systems Institute, and the prestigious Santa Fe Institute. These scientists discovered that CAS have several identifying features.[1]

**Interdependent adaptable agents.** CAS have locally interdependent agents that adapt their behavior to respond to environmental changes. More complex systems have more—and more diverse—agents with more complicated interactions and more levels of organizational hierarchy. Because advanced health care systems have myriad interlocking institutions, businesses, governmental agencies and people at many hierarchical levels, and because each agent of these systems can adapt to environmental changes, such systems can be highly complex.[2] Figure 1 shows that the U.S. health care system in general, and its consumer component in particular, is more complex than several other U.S. economic systems: to determine the agents involved in an average medical expenditure transaction, one must answer about a billion binary questions.[3]

**A challenge**

If social worlds are truly complex, then we might need to recast our various attempts at understanding, predicting, and manipulating their behavior. In some cases, this recasting may require a radical revision of the various approaches that we traditionally employ to meet these ends.

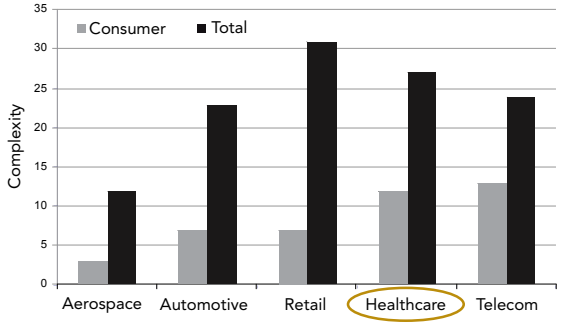
John Miller and Scott Page
*Complex Adaptive Systems*

**No central controller.** CAS lack a central authority controlling agent behavior; rather, agents self-organize. Health care systems also lack a central controller. For example, no central agency dictates how patients flow to doctors.

**Open.** CAS are open to the influence of the outside environment, which includes other CAS. Because health care systems are affected by general inflation, politics, unemployment, demographics and other environmental characteristics, they are open systems.

I THINK THE NEXT CENTURY WILL BE THE CENTURY OF COMPLEXITY.
—Stephen Hawking, Jan. 23, 2000

**Figure 1: Relative complexity of U.S. health care**

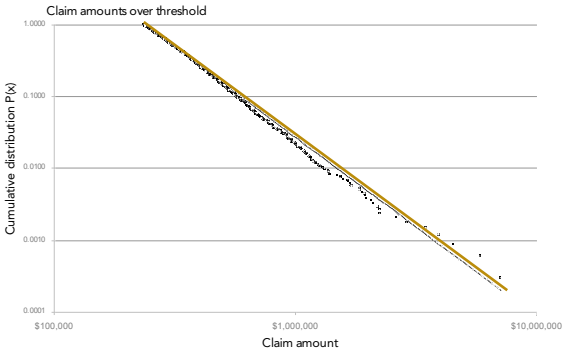


**Feedback.** Agent interactions include positive and negative feedback loops.[4] That is, Agent A behavior affects Agent B behavior, which feeds back to affect Agent A behavior (A ⇆ B). Health care systems have a rich web of feedback loops. For example, in contracting with providers, one health insurer's behavior affects the actions of other insurers (and Medicare), which then feed back to affect the original insurer: Insurer A ⇆ Insurer B.

**Power Law distributions.** CAS produce outputs with frequencies conforming to Power Law (Pareto) statistical distributions ( $p(x) \approx 1/x^n \Rightarrow \ln p(x) = a + b * \ln x$ ).[5] Health care systems are replete with Power Law outputs, from the incidence of epidemics to pharmaceutical sales.[6, 7] For example, Figure 2 is a log-log graph showing that medical expenditures above a threshold are Power Law distributed.

Thus, a health care system will exhibit common CAS characteristics, such as.[8]

**Figure 2: Power Law distribution of the SOA 1991/1992 large claims database (author's unpublished work)**




**Emergence.** The system's behavior as a whole will be qualitatively different than the behavior of its parts.[9] Therefore, to understand the system's behavior, we must do more than analyze its components.

**Hidden causality.** Because of the system's rich web of interactions and feedback, identifying causal chains (or even trend drivers) is generally impossible.

**Unpredictability.** Because of openness and interdependent non-linear dynamics, system behavior is fundamentally unpredictable for more than a short period of time (and cannot be modeled using the Gaussian family of probability distributions, the Law of Large Numbers, or the Central Limit Theorem).[10]

**Punctuated equilibria.** The system will have periods of relative quiescence punctuated by abrupt and dramatic upheavals, or catastrophes.

The remainder of this paper examines the impact of these CAS characteristics on how we identify, forecast and man-

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age medical expenditure trend drivers. For this purpose, it is useful to classify trend drivers as agent behaviors organized in three groups (borrowing classification terminology from Taleb[10] and Rumsfeld[11]):

**White Swans (known knowns):** Agent behaviors we believe we can identify, forecast and manage. Examples are consumer utilization, physician coding practice and provider contracting demands.

**Gray Swans (known unknowns):** Agent behaviors we can identify as having potentially significant impact. But we cannot accurately forecast their impact, and so cannot effectively manage them. Examples are production of blockbuster drugs, emerging medical technologies, flu epidemics and health care reform.

**Black Swans (unknown unknowns):** Behaviors we cannot identify, much less forecast or directly manage, such as the onset of AIDS. (But we can indirectly manage their risk, and the risk of Gray Swans, as discussed below.)

**When one is lost, any map will do**

This incident, related by the Hungarian Nobel Laureate Albert Szent-Gyorti and preserved in a poem by Holub (1977), happened during military maneuvers in Switzerland. The young lieutenant of a small Hungarian detachment in the Alps sent a reconnaissance unit into the icy wilderness. It began to snow immediately, snowed for 2 days, and the unit did not return. The lieutenant suffered, fearing that he had dispatched his own people to death. But on the third day the unit came back. Where had they been? How had they made their way? Yes, they said, we considered ourselves lost and waited for the end. And then one of us found a map in his pocket. That calmed us down. We pitched camp, lasted out the snowstorm, and then with the map we discovered our bearings. And here we are. The lieutenant borrowed this remarkable map and had a good look at it. He discovered to his astonishment that it was not a map of the Alps, but a map of the Pyrenees. This incident raises the intriguing possibility that when you are lost, any map will do.

Karl E. Weick
*Sensemaking in Organizations*

I AM CONVINCED THAT THE NATIONS AND PEOPLE WHO MASTER THE NEW SCIENCES OF COMPLEXITY WILL BECOME THE ECONOMIC, CULTURAL, AND POLITICAL SUPERPOWERS OF THE NEXT CENTURY.—Heinz Pagels, 1988

## IDENTIFYING TREND DRIVERS

Because of the complex nature of health care, traditional statistical methods cannot explicitly identify trend driver causal chains. For example, in 1992 the Lewin Group conducted two major regression studies analyzing more than 250 potential trend drivers for outpatient and physician expenditures, but appropriately cautioned that the results, although interesting, did not establish any causal relationships.[12, 13] Indeed, the only scientific method that can establish causal relationships from data is the randomized controlled experiment[14] (a method outside of the actuarial repertoire), but even this method often fails to establish causal chains in a complex system.

To better understand and identify trend drivers, we can expand our repertoire of methods:

**White Swans:** We will better understand the known knowns if we study the behavioral rules governing health care agent interactions (perhaps with controlled experiments), then develop simulations and games[15] based on these rules. Economics has taken significant strides in this direction with behavioral economics.[16]

**Gray Swans:** To better identify emerging known unknowns we can implement continual formal environmental scanning

(periodic scans are insufficient),[17] Bayesian classifier data mining,[18] and Delphi methods.[19, 20]

**Black Swans:** By definition, unknown unknowns are unidentifiable in advance.

## FORECASTING TREND DRIVER IMPACT

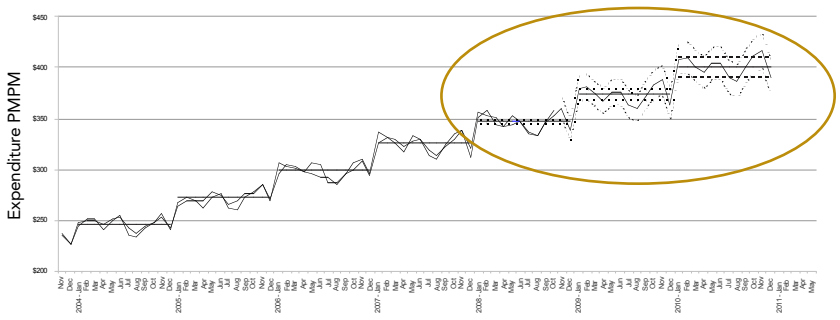
Despite monumental efforts, medical expenditure trend forecasts are notoriously inaccurate. For example, CMS one-year NHE drug trend projections during 1997-2007 missed actual trends by 2.7 percent on average,[21] and other actuarial forecasts appear to be equally error prone. We now know why: Complex system behavior is unpredictable beyond a near-term horizon. But here's what we can do:

**White Swans:** Simplify our forecasting methods (simpler methods usually perform better[22]), perform more frequent forecasts (monthly), include confidence intervals (see Figure 3), and analyze experience. Keep in mind: almost any map will do (see sidebar on page 18).

**Gray Swans:** Widen confidence intervals to reflect Power Law distributions and potential Gray Swans; employ simulation models and Delphi techniques to determine the fan of possible outcomes.

**Black Swans:** By definition, they cannot be identified or forecasted.

**Figure 3: Confidence intervals for medical expenditure forecasts (author's unpublished work)**




## MANAGING TREND DRIVERS

Health care executives often lament that managing medical expenditures is like squeezing the proverbial balloon: Expenditures always pop out somewhere else. It is true: Our current management methods may be inadequate to contain adverse risks posed even by White Swan trends, much less the potentially catastrophic risks posed by Gray and Black Swans. Complex adaptive systems require a different management approach, because agents readily adapt to being squeezed (see sidebar below).

**White Swans:** Revise the management approach: Rather than impose detailed rules on individual system agents, provide general strategy, incentives and resources,[23] all informed by behavioral research and simulation modeling results.

**Gray Swans:** Introduce an Enterprise Risk Management program focused on emerging trend drivers.[17]

**Black Swans:** In light of the knowledge that health care is subject to periodic dramatic upheavals similar to what we recently experienced in the financial sector, and that these upheavals can

**Think like a farmer**

It is more helpful to think like a farmer than an engineer or architect in designing a health care system. Engineers and architects need to design every detail of a system. This approach is possible because the responses of the component parts are mechanical and, therefore, predictable. In contrast, the farmer knows that he or she can do only so much. The farmer uses knowledge and evidence from past experience, and desires an optimum crop. However, in the end, the farmer simply creates the conditions under which a good crop is possible. The outcome is an emergent property of the natural system and cannot be predicted in detail.

Paul Plsek
*Crossing the Quality Chasm*

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come in clusters, reexamine the reserving, reinsurance, exclusion, risk-decoupling, and lifetime maximum policies of large insurers, reinsurers, and self-insured employers. And not least: relinquish the illusion of control.[24] ▼

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