Complexity Science Models of Financing Health and Social Security Fiscal Gaps

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COMPLEXITY SCIENCE MODELS OF FINANCING HEALTH AND SOCIAL SECURITY FISCAL GAPS

By
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INTRODUCTION

Many think health and Social Security markets and social insurance programs are broken because they are increasingly unaffordable for too many Americans. *Bending the cost curve down* has become a standard reference term for the main objective of reform proposals to slow cost increases or even reduce them. This paper presents an alternative model with preliminary results of statistical analyses of *complexity science* simulation models with historical data that quickly *bend the GDP curve up* to increase affordability.

This paper looks beyond popular reform models to self-organizing complexity science models based on chemistry, physics, and biology theories to suggest sustainable, long-term financial reform proposals. The foundation of these proposals is not based on orthodox market failure economic models but rather on thermodynamics in general and the time evolution of Shannon information entropy in particular:

- **Complexity Science**: One of the most important first principles of complexity science is open systems may eventually self-organize to degrade their far-from-equilibrium (FFE) gradients. That includes long-term inflation trends in health and retirement income and benefits cash flows.
- **Chemistry**: Ilya Prigogine helped develop the theory of *dissipative structures* to explain how chemical systems self-organize to degrade temperature, pressure, and other gradients. A majority of the quantitative analyses in the paper measured the size and stability of simulated gradient degradation during self-organization.
- **Physics**: Edwin Jaynes helped develop physics theories of *structured channels* and *maximum entropy production* to explain how physical systems can very quickly, even abruptly, self-organize to degrade energy gradients.
- **Biology**: The role of entropy in a theory of the *organization of life* in evolutionary biology by Harold Morowitz and Eric Smith was used to suggest parallels with the time evolution of entropy in health care markets and social insurance programs. A key conclusion is our nation's so-called *broken health care* is actually a cascade of continuous (or nearly so) phase transitions that seem to be turned on by networks of microscopic and emergent macroscopic variables, including entropy that function like gene switches.
- **Finance**: Simulation models of hedging income and benefits of Medicare, Medicaid, private health insurance, and Social Security in exchange-traded derivatives financial markets seem to quickly switch on intermediary cash flows that increase nominal annual GDP by about 11-14 percent. The models of Prigogine, Jaynes, and Morowitz & Smith applied to derivatives markets show how that most likely works.

ORGANIZATION OF PAPER

OVERVIEW OF COMPLEXITY SCIENCE FINANCIAL MODELS

Logic of Dissipative Structures & Structured Channels: One of the most common applications of complexity science models in physics, biology, chemistry, and many other scientific fields of study is to identify a *far-from-equilibrium* gradient in a system and then seek to document that the system self-organizes in some manner to degrade or offset the FFE gradient. A small perturbation causes a temporary deviation from equilibrium. An ongoing flow of perturbations eventually causes the system to pass a threshold, beyond which it begins to build dissipative structures to degrade or offset the FFE gradient, rather than return to equilibrium.

For example, a rain shower in the afternoon in a tropical jungle cools or degrades a temperature gradient that increased earlier in the day as the sun warmed the jungle. In a process called evapotranspiration roots of plants and trees suck water out of the ground and transport it to their leaves where it evaporates. The evaporated water rises into the atmosphere eventually to form clouds. The clouds in time release rain showers, and the jungle cools. The cycle of self-organized production of rain showers to cool the jungle repeats itself, again and again and again. Clouds with rain showers are *dissipative structures* because they cool the hot jungle.[1]

This paper applied the same idea of self-organized degradation of jungle temperature gradients to the potential self-organized degradation of inflationary trends in health and Social Security income (premiums and taxes) and outgo (benefits) cash flows. The main research question is what are the dissipative structures that self-organization produces to cool (or offset) long-term FFE inflation in health and Social Security cash flows? The concepts of entropy-driven biogenesis (organization of life) in part based on *gene switching and signaling* from biology, dissipative structures from chemistry, and *maximum entropy production* with fast *structured channel formation* from physics were joined together to provide a general explanatory framework to suggest an answer to this question.

Edwin Jaynes advanced the concept of structured channels, and Ilya Prigogine advanced the concept of dissipative structures. Although different terminology is used, they appear to be very similar FFE concepts for the source of the offset to or the degrading agent of FFE gradients.[2] However, as discussed later in this paper, some aspects of their behaviors are different. First, Jaynes explained that the formation of structured channels can be very fast.

Second, Prigogine thought that dissipative structures were realized in low or minimum entropy production environments. To the contrary, Jaynes believed structured channels were realized in maximum entropy production environments. Third, Jaynes believed that the time evolution of entropy in many instances could be the most important determinant

[1] For further discussion of cooling jungle temperature gradients see Into the Cool by Eric D. Schneider & Dorian Sagan, University of Chicago Press, March 2005.
[2] Throughout the remainder of this paper "dissipative structures" will be used rather than "structured channels" based on the assumption that they are the same.

of the of the time evolution of macroscopic explanatory variables of FFE systems, such as the rising cost of health care.

Quantifying the Time Evolution of Dissipative Structures Cash Flows: A variation on estimating Solow residuals for total factor productivity from macroeconomic growth theory quantified the time evolution of these cash flows. Statisticians will recognize that an intercept dummy variable that measures the time evolution of a variation of the Solow residual is identical to a dummy variable that measures the time evolution of an *intercept order parameter* (sometimes also called a *critical exponent*) for second-order or continuous phase transitions.

The answer to the main research question is the dissipative structures are new income cash flows that are uniquely determined by the characteristics of each inflationary income and outgo cash flow for each health and Social Security market and social insurance program. The emergence of these new cash flows is triggered just like a single gene or combinations of genes switch chemical reactions on and off to produce biological development. Hedging in exchange-traded derivatives markets turns on self-organizing calculations of how large dissipative cash flows should be because that's how much GDP should increase to degrade FFE gradients and establish stability.[3]

These new spread gains cash flows produce real, actual increases in GDP. That is to say, self-organizing activity behavior requires computational rules to decide the magnitude and timing of emergent cash flows. This paper essentially reversed engineered what those rules might have been had the best exchange hedging practices been used. Computational rules use hedged spreads for every natural hedger to simultaneously calculate how much the spreads need to increase or decrease across all hedgers to cause GDP to increase to degrade the FFE income and paid benefits gradients. From a different perspective the dissipative structure behaves like a bicycle derailleur. It finds a balance between the bicycle's rider's ability to continuously pedal and an acceptable speed to ride up/down a given height gradient or slope.

The steps and results of the computational rules for self-organizing are similar to the way the Federal Reserve in 2010-2011 partially monetized the national debt. The Federal Reserve, by analogy, has computational rules that "measure" economic activity to "determine" how much the economy should be stimulated in order to actually buy back government securities. Then money is pumped into the economy.

Dissipative structures may be real or may only exist in computational space to provide estimates of key parameters for further distribution to the self-organizing process. If they are real, then somehow markets and/or governments actually pay hedgers their share of the dissipative structure cash flow over time. If they are computational, they will cause

[3] The author found just one citation in the literature on the financial impact of hedging. In a March 1999 speech former Federal Reserve Chairman Alan Greenspan suggested hedging and information technology improvements reduced the spread between residential mortgage rates and government securities by about 70 basis points. No formal details of his estimate were provided and the speech is available at the Federal Reserve website.

GDP to endogenously grow as insurance markets and social insurance programs prosper and the money supply adjusts to changed macroeconomic conditions.

Hedging Spreads: Hedging the spreads between income and benefits are simulated for Medicare, Medicaid, private health insurance, and Social Security in two hypothetical Medicare Part A FICA taxes and benefits futures contracts. The hypothetical results of the statistical analyses are consistent with the proposition that dissipative structures emerge as new cash flows. There are two sources. The first source is real or computational increases in the spread between hedged premiums and benefits for natural hedgers like governments and insurers who are short FICA and long benefits futures positions. The second source is real or computational decreases in the spreads between hedged benefits and premiums for natural hedgers like employers and employees who are long FICA and short benefits futures positions.[4]

The dissipative structure in hedged, FFE health and Social Security is spread gains. Spread gains are aggregations of component gains. There are *efficiency gains* for premiums and benefits, *hedging gains* for premiums and benefits, and the sum of efficiency gains plus hedging gains is called *economic gains* for premiums and benefits. The difference between economic gains for premiums and benefits are called *spread gains*.[5] Results of statistical analyses of the combined spread gains cash flows are shown not to be statistically different from key mathematical requirements contained in the theory of dissipative structures advanced by Ilya Prigogine.

These mathematical requirements are dissipative structures should (1) be stable, (2) offset FFE gradients, and (3) be correlated across *macroscopic distances*. Solutions to first and second-order difference equations meet these requirements for each cash flow because they are all moving equilibria equations (with eigenvalues not statistically different from one (1)) that are univariate linear functions of time. Meeting the three requirements allows straightforward computation of 75-year fiscal gap offsets.

Brief Summaries of Quantitative Analyses: The following two brief summaries of the results are based on an econometric simulation model that hedges all the actual incomes and benefits, respectively, for Medicare (Parts A & B but not D), Medicaid (combined federal and state), Social Security (OASDI), and private health insurance in two hypothetical futures contracts. The first is a hypothetical Medicare Part A FICA futures contract that hedges all income flows, and the second is a hypothetical Part A benefits futures contract that hedges all benefits flows. Both futures contracts were based on the trading performance of the Chicago Board of Trade 10-year Treasury notes futures contract for the time period 1982-2003. [6]

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[4] The second group of employers and employees want benefits to be higher and premiums lower. Therefore they welcome reductions in the spread or difference between premiums less benefits. The first group of governments and insurers are just the opposite. They want premiums (or tax cash flows) to be higher and benefits lower. They want the spread or difference to be larger between premiums less benefits.
[5] See Technical Appendix A that defines and explains these components of *derivatives spread gains*.
[6] Government taxes such as FICA taxes, general fund taxes (corporate and personal income taxes), and Part B premiums are "income" in this report, as well as private health insurance premiums.

The first is the value of the new annual cash (dissipative structure) as a percent of the combined value in income and outgo by system. The second is the size of the fiscal gap for Medicare, Medicaid, and Social Security over a 75-year period (2009-2083):

- Preliminary estimates of the size of the new annual cash flow for each market and social insurance program is about 50 percent of the respective combined value of its income and its benefits.
- A fiscal gap is the present value of the estimated unfunded liabilities as a percent of the present value of GDP for 2009-2083. A dissipative structure offset to a fiscal gap is the present value of the dissipative cash flow as a percent of the present value of the same GDP for the same time period. The Congressional Budget Office (CBO) estimates of the fiscal gap for Medicare, Medicaid, and Social Security for this period are about 7-9 percent with an 8 percent midpoint. *Tot Gov* denotes the combined fiscal gap offset for Medicare, Medicaid, and Social Security. Estimates of spread gains fiscal gap offsets include: [7]
    - At a 5 percent discount rate Tot Gov fiscal gap offset is about 4.4 percent, equal to about 54.8 percent (54.8% = 4.4%/8.0%) of the 8 percent midpoint. M & M (Medicare + Medicaid) offset is about 37.8 percent, and OASDI is about 17.1 percent, respectively, of the 8.0 percent CBO midpoint.[8]
    - At a 3 percent discount rate Tot Gov fiscal gap offset is about 97.6 percent, M & M is about 67.6 percent, and OASDI is about 30.0 percent, respectively, of the 8.0 percent CBO midpoint.
    - Increasing discount rates further from 6 to 10 percent reduces Tot Gov percent of the 8.0 CBO midpoint from about 43 to 21 percent.
    - GDP increases in the same year about $1 billion for every $1 billion increase in the dissipative structure cash flow.

THEORIES OF DISSIPATIVE STRUCTURES & STRUCTURED CHANNELS

In the simplest case scientists usually treat shocks to equilibrium as temporary disturbances, drawn from some probability distribution, that in time die out, permitting a system to return to its old equilibrium. But what happens to that system if disturbances do not die out, but cumulatively take it further and further away from equilibrium? Then they accumulate like snow drifting against a wall in the shade rather than melting away in direct sunlight. In this latter case in complexity science jargon the open system is said to be increasingly *far-from-equilibrium.*[9]

[7] Fiscal gaps for state and federal governments for 2009-2083 are the sum of the present values of Medicaid, Medicare, and Social Security unfunded obligations divided by the present value of GDP. The gap measures "the immediate and permanent increase in taxes or reduction in spending that would keep the long-term debt-to-GDP ratio at its current level" (Auerbach, Brookings Institution, "An Update on the Economic and Fiscal Crises: 2009 and Beyond", 2009).
[8] M & M is the abbreviation for the combined Medicare and Medicaid fiscal gap and its offset. OASDI is the usual abbreviation for combined Old Age & Survivors Insurance (OASI) and Disability Insurance (DI).
[9] In the simplest case a time series is in equilibrium when two successive values are equal or nearly so (≤ 2 percent difference in this report). That simple system is increasingly far-from-equilibrium when successive values always increase the difference between the current value and the most recent equilibrium value by some amount. Another

Prigogine on Entropy & Dissipative Structures: To explain what happens to a FFE system, Ilya Prigogine developed a theory of *dissipative structures*, for which he was awarded the Nobel Prize for chemistry in 1977. He believed that many disturbances in fact diminish as commonly believed, and a system returns to its prior or new equilibrium. But he also claimed an increasingly FFE system passes a threshold, beyond which it does not return to its original equilibrium. Rather it begins to build a new FFE *dissipative structure* with three remarkable features.[10] First, that structure is dynamically stable even if the system was initially not. Second, it degrades or offsets the original increasingly FFE trend that led to its "emergence".[11] Third, the law of large numbers no longer applies to dissipative structures. That reduces the randomness of interactions among multiple dissipative structures that increases their correlations across macroscopic distances.

Jaynes on Entropy & Structured Channels: In classical thermodynamics entropy is the logarithm of the volume of the phase space. In information theory entropy is the logarithm of the "number of ways a macrostate can be realized". Said another way, the "macrostate of higher entropy can be realized in overwhelmingly more ways".[12] Jaynes thought information entropy is a measure of reproducibility in irreversible open systems, not disorder as so many scientists believe.

He believed that microscopic fluctuations are "the driving force that makes an irreversible process go" with a "systematic movement of the macrostate at a drift velocity proportional to the entropy gradient times the mean-square fluctuation". Depending on circumstances, entropy is a determinant of the size and stability of emerging macrostates. In his conclusion to his paper "Macroscopic Prediction", he said:

> "Most recent discussions of macrophenomena outside of physical chemistry concentrate entirely on the dynamics (microscopic equations of motion or an

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increasingly far-from-equilibrium system is a limit cycle with growing amplitude. Both are found in health and Social Security time series, although the former is more common.

[10] Although Prigogine received the chemistry Nobel Prize, his theories are still being modified and challenged by other chemists and thermodynamics experts. See for example papers by the Russian chemist Georgi Pavlovich Gladyshev at www.statemaster.com and www.eoht.com. The author suggests to readers that the results of empirical simulation modeling in this paper are very preliminary but apparently consistent with three major claims about dissipative structures offered by Prigogine. These consistencies are sufficient to encourage other researchers to investigate complexity science modeling of health and Social Security as an additional or alternative policy option to be discussed in our nation's ongoing health care reform debates.

[11] The example from chemistry he described in his Nobel Prize lecture was the Bénard instability, one of the first empirical chemistry applications of complexity science. A horizontal fluid is heated from below creating a temperature gradient or spread between the temperatures at the bottom and top of the fluid. "In the case of the Bénard convection, we may imagine that there are always small convections currents appearing as fluctuations from the average state; but below a certain critical value of the temperature gradient, these fluctuations are damped and disappear. However, above some critical value certain fluctuations are amplified and give rise to a macroscopic current. A new supermolecular order appears which corresponds basically to a giant fluctuation stabilized by exchanges of energy with the outside world. This is the order characterized by the emergence of "dissipative structures" (See *Time, Structure and Fluctuations*; December 8, 1977; p. 267, at www.nobelprize.org). Exceeding a FFE *critical value* is like a gene switch that triggers further biological development when, say, a protein exceeds a concentration threshold. The dissipative structure degrades or offsets the Bénard temperature gradient by replacing conduction with convection heating.

[12] E.T. Jaynes," Macroscopic Prediction" in Complex Systems—Operational Approaches in Neurobiology, Physics, and Computers, H. Haken, Ed.; Springer—Verlag, Berlin (1985); pp. 254-269. The paper is online at www.bayes.wustl.edu/etj/articles/macroscopicprediction, pdf, p. 6.

> assumed dynamical model at a higher level, deterministic or stochastic and ignore the entropy factors of macrostates altogether. Indeed, we expect that such efforts will succeed fairly well if the macrostates of interest do not differ greatly in entropy. But there are puzzling cases, as noted in the Introduction, where macrobehavior seems hard to understand in terms of any reasonable dynamics alone. In these cases, the entropy factors may be the missing ingredient; as we learned from Gibbs, prediction of chemical equilibrium could not have succeeded at all until the macroscopic entropy was recognized." [13]

Horowitz & Smith on Sudden Formation of Macroscopic Order: In their paper "Energy Flow and the Organization of Life" Horowitz and Smith claim that:

> "Entropy can depend on currents as well as on configurations. When it does, the principle of free energy minimization for open systems, which is derived from entropy maximization, can be extended to driven systems…
>
> "The resulting entropy-maximization principles can predict the spontaneous formation of currents, whereas the equilibrium entropy is maximized on currentless states…
>
> "The presence of positive feedback in a current-carrying system can create a threshold for the sudden formation of macroscopic order, and the crossing of this threshold is a phase transition equivalent in all statistical respect to equilibrium phase transitions. The ordered state creates a channel between the environment's input and output reservoirs with much better conductance that the equilibrium state. Order in turn is maintained by energy extracted for the current between the reservoirs." [14]

A lightning bolt is an example of the sudden formation of macroscopic order "when air suffers dielectric breakdown in response to a charge separation between the upper atmosphere and the ground." [15] Hedging Medicare, Medicaid, Social Security, and private health insurance in exchange-traded derivatives markets likewise triggers the sudden formation of new cash flows as if they were struck by financial lightning.

They also said "life creates transport channels in the chemical domain, employing the more concentrated energy flows associated with molecular re-arrangements". To paraphrase the previous sentence, "[hedging] creates transport channels in the [financial] domain, employing the more concentrated energy flows associated with [financial engineering] re-arrangements." By further analogy, exchange-traded derivatives markets are a substrate where risky financial assets are disassembled and then recombined into

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[13] Ibid., pp. 14- 16.
[14] Morowitz, H. & Smith, E., "Energy Flow and the Organization of Life", at www.genome.ad.jp/kegg/, pp. 4, 5.
[15] Ibid. p. 1.

new assets just as chemical bonds of reagents are broken and then recombined to form new molecules with new energetic capabilities for further downstream reformulations. These new assets are then delivered over time and across markets to hedgers. The process monetizes health.

Monetizing Health & the Demographic Dividend: Health insurance in part, but not entirely, monetizes health. Health insurance companies receive premiums from employers to pay for health insurance for employees and their families. In addition some insurers pay employees and their families to participate in various preventative health programs. A preventative health initiative in small measure further monetizes health.

On a much larger scale, health in China and India has been further monetized. The *demographic dividend* is

> "the economic boost that countries can receive when they shift from high rates of fertility and mortality—women having lots of children, many of whom die young—to low birthrates and longer life expectancies.
>
> "In a country where this demographic transition is taking place—thanks to improvements in health and other forces—the resulting temporarily large share of working–age people can, under the right circumstances, fuel a strong economic transition as well. Under the wrong circumstances, it can lead to civil upheaval.
>
> "At the start of the demographic transition…women still have lots of children, but many more of those children survive into adulthood and old age. Only after a while do birthrates decline. And between those two moments not only do populations increase but the average age of people also drops. You get a youth bulge.
>
> "…many economies in East Asia in the 1980s and 1990s experienced significant growth that could be attributed to the demographic dividend because educational, social, and government policies were in place to take advantage of the bulge generation's numbers and potential economic productivity."[16]

The "economic boost" countries get when they shift from high to low rates of fertility and mortality, by analogy, is probably a dissipative structure. Bloom and his colleagues "calculate that as much as one-third of the growth" in East Asia boom years were due to these health changes.[17] The idea of a significant "economic boost" for China and India parallels the tentative empirical findings of significant increases in GDP from hedging.

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[16] Time magazine on March 17, 2011, published "Ten Ideas That Will Change the World". One of the ideas was the demographic dividend. These quoted remarks appeared in a Harvard School of Public Health newsletter (4-17-2011) with the title "Time Magazine's '*Ten Ideas That Will Change the World*" Features HSPH Faculty Research", p. 1. It is available at www.hsph.harvard.edu/news/features/coverage-in-the-media/demographic-dividend-time- bloom/index.
[17] Harvard Public Health Review, "Pigs, Pythons, and Economic Miracles", Spring 2005, p. 3.

TABLE 1: TOTAL ACTUAL VALUES, FAR-FROM-EQUILIBRIUM (FFE) VALUES, AND SPREAD GAINS (SG) VALUES FOR 1982-2003 ($BILLIONS)

VARIABLES	TOTAL ACTUAL	TOTAL FFE **	TOTAL SG		FFE % of ACTUAL	SG % of ACTUAL	SG % of FFE
PI Premiums	$6,414.4	$6,184.2	$2,893.3		96.4%	45.1%	46.8%
PI Benefits	$5,279.0	$5,099.5	$2,745.5		96.6%	52.0%	53.8%
Total PI	$11,693.4	$11,283.7	$5,638.8		96.5%	48.2%	50.0%
HI FICA Taxes	$1,995.3	$1,842.6	$2,325.5		92.3%	116.5%	126.2%
HI Benefits	$2,013.3	$783.5	$2,021.0		38.9%	100.4%	257.9%
Total HI	$4,008.6	$2,626.1	$4,346.5		65.5%	108.4%	165.5%
SMI GF+P	$1,256.7	$336.7	$990.3		26.8%	78.8%	294.1%
SMI Benefits	$1,245.5	$1,245.5	$291.6		100.0%	23.4%	23.4%
Total SMI	$2,502.2	$1,582.2	$1,281.9		63.2%	51.2%	81.0%
MCAID Total	$2,802.6	$2,802.6	$1,186.3		100.0%	42.3%	42.3%
MCAID Ben	$2,642.3	$2,642.3	$1,164.5		100.0%	44.1%	44.1%
Total MCAID	$5,444.9	$5,444.9	$2,350.8		100.0%	43.2%	43.2%
OASDI FICA	$7,318.0	$3,729.8	$2,532.8		51.0%	34.6%	67.9%
OASDI Ben	$6,521.8	$6,521.8	$3,136.5		100.0%	48.1%	48.1%
Total OASDI	$13,839.8	$10,251.6	$5,669.3		74.1%	41.0%	55.3%
Total Income	$19,787.0	$14,895.9	$9,928.2		75.3%	50.2%	66.7%
Total Benefits	$17,701.9	$16,292.6	$9,359.1		92.0%	52.9%	57.4%
Total Inc + Ben	$37,488.9	$31,188.5	$19,287.3		83.2%	51.4%	61.8%
** All Total FFEs increase monotonically during 1982-2003 except HI FICA, HI benefits, SMI GF+P (Part B general funds + premiums), and OASDI FICA that follow limit cycles.							

FIGURE 1

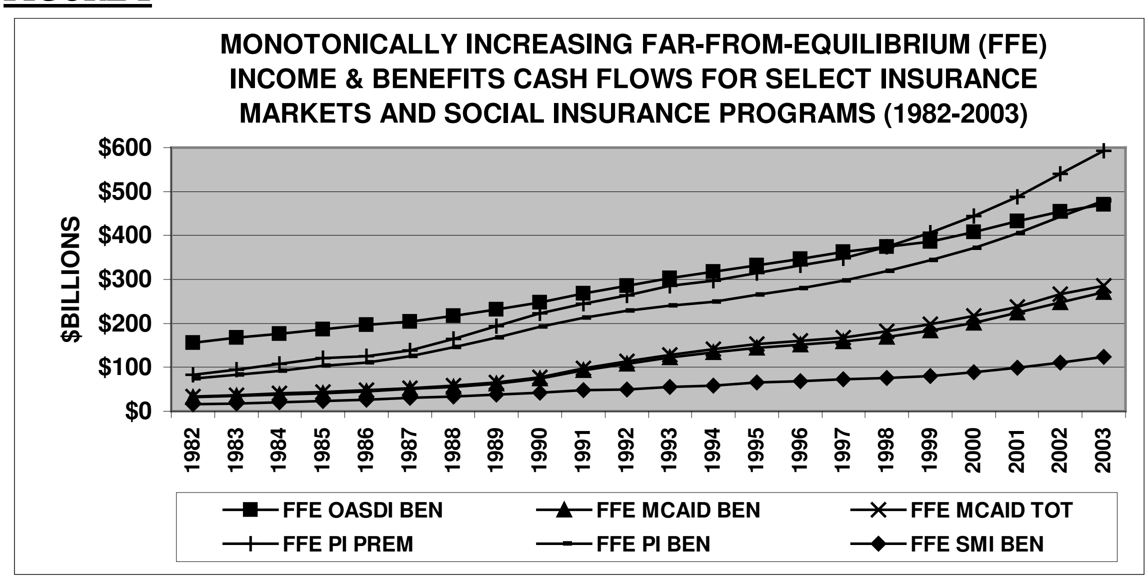
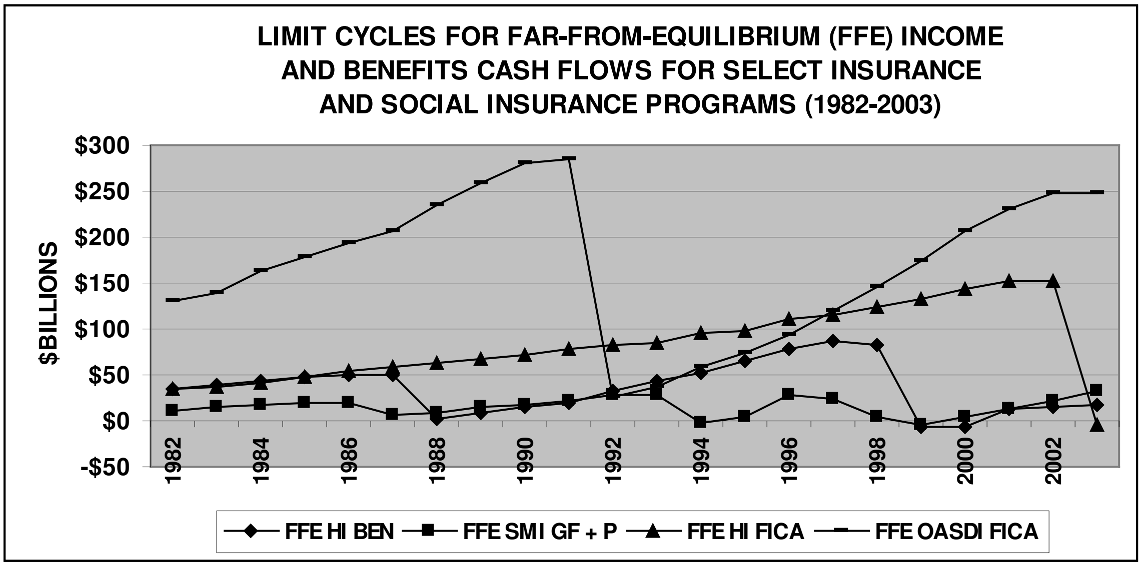


FIGURE 2



Measuring FFE Cash Flows: This paper is the first of at least two papers on gradient degradation by dissipative structures. This first paper presents preliminary documentation that hedging produces quick gradient degradation results consistent with Jaynes and Horowitz & Smith. The magnitude and stability of the degradation results are consistent with Prigogine and Jaynes. The as yet unwritten second paper will attempt to quantitatively ascertain whether the time evolution of information entropy is also present.

Table 1 and Figures 1-3 summarize key FFE income (tax) and benefits data for health and Social Security. Table 1 shows that health and Social Security income (insurance premiums and taxes that include FICA, general fund, and Part B premiums taxes) and benefits cash flows to varying degrees are FFE. *Total Actual* in the first column in Table 1 is the sum of the actual annual premiums, benefits, and combined premiums plus benefits for 1982-2003. *Total FFE* in the second column in Table 1 is the actual annual FFE premiums, FFE benefits, and combined FFE premiums plus FFE benefits for 1982-2003. *Total SG* in the third column in Table 1 are statistical estimates of the cumulative spread gains or dissipative structures.

Broadly speaking, all time series in Table 1 fall into two different groups or patterns. All Total FFEs increase monotonically during 1982-2003 except HI benefits, SMI GF+P (Part B general funds + premiums) and OASDI FICA that follow limit cycles. First, in the former group they can closely follow the actual time series that make the sum of annual FFE about 90-100 percent of the sum of actual annual values. The constant elasticity estimate of a 1 percent change in total FFE is about a 1.40 percent change in total spread gains. Second, in the latter group they can follow limit cycles that make FFE about 30-60 percent of actual values. The constant elasticity estimate of a 1 percent change in total FFE is about a 0.36 percent change in total spread gains for limit cycles.

Figure 1 contains six graphs of the FFE time series for income and benefits for the five insurance markets and social insurance programs. The time evolution of these six FFE cash flows increases monotonically for the 1982-2003 time period. In Figure 2 FFE time series for OASDI FICA, HI FICA, HI BEN, SMI GF+P (general funds plus premiums) are periodic limit cycles that rise like logistic curves, then collapse to near zero, only to rise again. Periods range from 5 to more than 20 years.

Dissipative Structures & Stable Moving Equilibria: Hedging these FFE cash flows in exchange-traded derivatives markets may act as a gene switch that turns on the self-organizing capabilities to compute the magnitude of and produce dissipative structures with the same three remarkable features described by Prigogine for the Bénard instability.

First, statistical estimates of solutions equations to first and second-order difference equations showed that the only or dominant eigenvalue was not statistically different from one (1). That result in combination with other details in Technical Appendix B showed that the solutions to the difference equations were consistent with linear functions of time making them *moving equilibria,* which are stable.

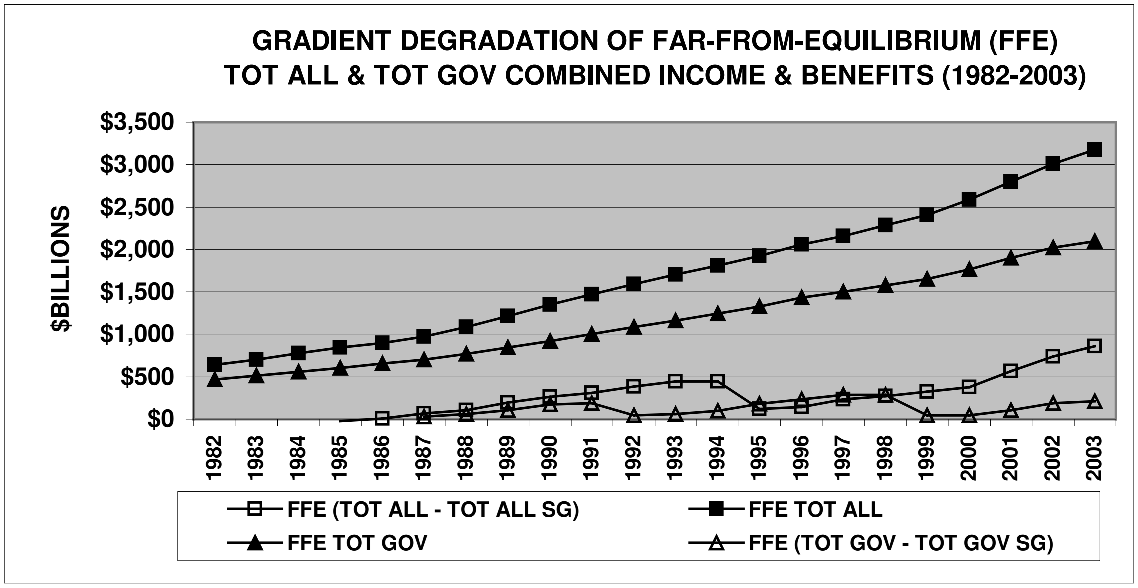
Second, the dissipative cash flows on average were about 50 percent of the combined income and benefits cash flows for all cash flows except Medicare Part A (hospital insurance) that was about 100 percent.

Third, the dissipative structures for Medicare, Medicaid, private health insurance, and Social Security all had eigenvalues not statistically different from one (1) and were moving equilibria linear functions of time. That all solutions were linear in time showed examples of increased order of correlations across macroscopic distances.

Figure 3 shows the gradient degradations for FFE all health and Social Security (Tot All) and for FFE all government (Tot Gov), discussed in the second bullet point immediately above. The monotonically increasing line with a black rectangle is the FFE Tot All; the limit cycle line with an empty black rectangle is the FFE (Tot All – Tot All SG). The degradation for FFE Tot All turns a monotonically increasing time series into a limit cycle with increasing amplitude. The degradation of FFE (Tot Gov – Tot Gov SG) has the same general limit cycle pattern like FFE (Tot All – Tot All SG) except the periodicity is shorter.[18]

[18] Generally speaking, the cutoff for equilibrium for this first, preliminary analysis of spread gains is that the difference between two consecutive values be less than or equal to 2 percent. In the FFE (Tot Gov – Tot Gov SG) time series there were 4 instances that the year-to-year percent changes were 2.8, 2.5, 2.7, and 2.7. When these values were incorporated into the analyses, the limit cycle emerged.

FIGURE 3



SPREAD HEDGING IN MEDICARE FUTURES CONTRACTS

Spread Hedging Precedents: *Spread hedging* is simultaneously hedging two or more risks in two or more different contracts at one or more exchanges. It expands the possibilities of customized risk management strategies for diverse natural hedgers and increases liquidity for all market participants including professional arbitragers. Spread hedging has a long tradition in exchange-traded derivatives markets like futures and options contracts.

For example, *hedging the crack* is a reference to catalytic cracking of crude oil into refined products. An oil refiner, for example, *hedges the crack* at the New York Mercantile Exchange when it simultaneously hedges the risks of paying higher-than-expected crude oil prices by buying crude oil futures and being paid lower-than-expected refined products prices such as heating oil, gasoline, or jet fuel by selling refined products contracts.

“Hedging the crush” is a reference to crushing soy beans into soy bean meal and soy bean oil. A soy bean processor *hedges the crush* when it buys soy bean futures contracts at the Chicago Board of Trade to hedge higher-than-expected soy bean prices and sells soy bean meal and oil contracts to hedge lower-than-expected meal and oil prices.

In the alliterative tradition of futures markets, the phrase *hedging the cure* can be used as a reference to insurers and government simultaneously selling premium and tax futures contracts to hedge against lower-than-expected premium and tax cash flows and buying benefits futures contracts to hedge against higher-than-expected benefits payments. Just the opposite is true for employers and employees who hedge or have a fiduciary agent hedge on their behalf.[19] They can buy premium futures contracts to hedge against the risks of higher-than-expected premiums and sell benefits futures contracts to hedge against lower-than-expected benefits.

Cure Spread Hedging in a Hypothetical Medicare Part A FICA and Benefits Contracts: How should health and Social Security cash flows be hedged in a first-generation exchange-traded environment? The answer is probably launching one spread market with two cash settled futures contracts for Medicare Part A FICA taxes and Part A benefits. The trading units, respectively, for these two contracts are Part A FICA taxes per Part A beneficiary and Part A benefits per Part A beneficiary.

Over time additional futures contracts specifically designed for Medicare, Medicaid, Social Security, and private health insurance can be launched to reduce the "basis risk" of hedging. The glide path of expanding futures markets over time is adding more contracts that reduce basis risk by increasing correlations (positive or negative) between unhedged cash flows and contract trading units.

Simulating Hedging in Medicare Futures Contract Requires Data on the Trading Performance of a Real Futures Contract—Which One?: The three most important trading performance measures of a futures contract are trading volume, open interest, and deliveries. Trading volume is the number of contracts traded each business day that can be aggregated to monthly and yearly levels. Open interest is the number of outstanding contracts at the end of trading each business day. Deliveries are the number of contracts held to maturity for a given trading month.

Generally, rising trading volume, open interest, and deliveries over time indicate increasingly liquid or efficient markets. Likewise, competitive markets are defined by whether any given buyer (or seller) can move the current market price. Buyers and sellers want to hedge larger cash flows without adversely moving the price to do so.

The hypothetical Part A FICA and benefits futures contracts could have been endowed with the trading performance of some other futures contract. An ideal contract should:

- be a contract that was solidly, rather than spectacularly successful after its launch. The 10-year Treasury notes contract was chosen because it is a work-horse, second tier successful contract. It is neither a first tier, blockbuster success like Treasury bonds or eurodollars nor a bottom tier contract that traded poorly but nonetheless survived.
- avoid contracts with very short maturities like Treasury bills or long maturities like Treasury bonds. The maturity of 10-year notes better matches the average

[19] Smaller, family-owned farms rarely hedge themselves. Rather, grain elevators typically offer these farmers fixed prices for future delivery on a given day. The elevators then hedge these fixed price purchases in an appropriate grain futures contract traded at a CFTC regulated commodity exchange. It is highly likely that insurance exchanges conceived in the health care reform legislation as well as other financial entities will offer employers and employees fixed premiums and benefits and then hedge their commitments just as elevators hedge their fixed prices to small, family-owned farms.

time horizon of many stakeholders in health and Social Security business and policy decision-making.

- be a contract that started after 1966 when Medicare and Medicaid started but at least 20 years or more before 2004-2005 when the research for this and other papers and book drafts began. [20] The 10-year note began trading in 1982. It is very important to include a futures contract launch to study the early time evolution of the impact of hedging on dissipative structures.
- be an interest rate contract, if possible. The federal government understands interest rate derivatives because all primary government securities dealers and many holders of these securities in secondary markets hedge. Also, many health insurers, employers, and providers routinely now hedge their interest rate risks. A core appreciation for hedging and expertise in interest rate trade execution among many of the expected long and short hedgers in a Medicare FICA futures contract will speed up the acceptance of hedging in these new futures contracts. Hedging health and Social Security cash flows is not any different in its essentials from hedging interest rates.[21]

For all these reasons the data analyses in this paper are for 1982-2003, unless otherwise noted. All statistical tests, including autocorrelation in this paper are small sample tests based on the small sample size (≤ 21) and the appropriate number of degrees of freedom. Data after 2003 that are now available in the public domain will be included in the near future to further update these analyses. Even so, the data set with post 2003 available data may still require small statistical sampling tests.

Cure Spread Gains Are Dissipative Structures: Complexity science models of health and Social Security reform in this paper are initially focused on insurers in the private sector and government (mainly state & federal) in the public sector. Insurers receive premiums and pay benefits. Governments (receive combinations of FICA taxes, general funds taxes, or some premium income (mainly Medicare Part B SMI) and pay benefits. As fiduciary agents, capital markets will sell premiums futures contracts to hedge the possibility that their insurer and government clients might face unexpected falling income. They will buy benefits futures contracts to hedge the possibility that those same clients might face unexpected rising benefits.

However, there must be hedgers to take the opposite sides of those insurer and government short hedges for premiums and taxes and long hedges for benefits. Those opposite, natural hedgers are employers, providers, and employees (beneficiaries) who

[20] The research results reported in this paper began with a draft book submitted for publication consideration in 2005 titled Hedging Chaotic Private Health Insurance Markets and the Uninsured and a revised draft submitted to a second publisher for consideration in 2006. Neither was accepted for publication. A paper focusing on estimating dissipative structures as fiscal gap offsets was submitted for publication consideration in an academic journal in 2009. It was not accepted. This draft paper is a revised and extended version of previous 2009 and 2010 papers.
[21] Very quickly a new specialty in financial risk management similar to financial engineering will be *financial epidemiology*. The art and science of hedging a covered life is really no different than hedging a 20-year Treasury bond or a barrel of crude oil.

pay cash premiums and taxes and receive cash benefits. They buy premiums futures contracts to hedge unexpected increased premiums and sell benefits futures contracts to hedge unexpected decreased benefits.

How do self-organizing health insurance markets and social insurance government programs compute what the magnitude of the dissipative structure cash flow should be? All else equal, governments and insurers would like premiums/taxes to be higher and benefits to be lower. In spread terms that means they want the spread between premiums/taxes and benefits to increase. For example, let current premiums/taxes be $100 and let benefits be $80. The initial spread is $20 ($100-$80=$20). If premiums/taxes increase to $110 and benefits fall to $75, the final spread is now $35 ($110-$75=$35). This pay premiums and receive benefits cure spread gain is $15 ($35-$20) for government and insurers.

Employers and employees are just the opposite.[22] They buy premium/tax futures contract to protect themselves from higher than expected premiums/taxes and sell benefits futures contracts to protect themselves unexpected decreases in benefits. In spread terms they want the spread between premiums/taxes and benefits to decrease. For example as for governments and insurers, let current premiums/taxes be $100 and let benefits be $80. The spread is $20 ($100-$80=$20). Now let premiums/taxes decrease to $90 and benefits rise to $85. The spread is now $5 ($90-$85=$5). This cure spread gain is minus -$15 ($5-$20) or $15 net to employers and employees. The combined cure spread gains for all hedgers are $30 ($15 + $15=$30). Two sets of statistical estimates of cure spreads gains must be estimated. One is for governments and insurers; the other is for employers and employees. They are not necessarily the same, and the signs of the spread changes are opposite.

In the statistical analysis of the time evolution of dissipative structures for the governments and insurers natural hedgers regression coefficients for premiums were positive and coefficients for benefits were negative that determined the spread gains for this population. The converse case was just the opposite for the population of employers and employees. Their regression premiums and benefits coefficients were negative and positive, respectively. The number of intercept dummy variables was unchanged, but by varying the number of years spanning each dummy variable, the signs of the regression coefficients flipped.

That each set of dummy variables can generate opposite signs of regression coefficients is just like cellular signaling pathways turned on and off by a single protein:

> "In cancer, the protein known as TFG-beta is both a blessing and a curse. Among cells just beginning to turn malignant, it acts as a tumor suppressor, inhibiting their growth. But among later stage cancers this protein that also regulates wound

[22] Rather than listing all the natural hedgers in this group, just *employers and employees* will be referenced.

> healing and cellular growth becomes a tumor promoter that provokes metastasis".[23]

Varying the number of years spanning each dummy variable apparently sorted the two natural hedgers groups by how quickly their spread gains grew. Surprisingly, turning cellular signaling pathways on and off by the maturity of earlier versus later stages of cancer growth may be just like switching on and off the signs of spread gains by how quickly spread gains grow--sooner or later.

MODELING DISSIPATIVE STRUCTURES

Data Sources: Health insurance premiums and benefits annual data from 1960-2003 were obtained from the National Expenditures time series NHE03 then available at the Center for Medicare and Medicaid Services (CMS) website (cms.gov). That file is updated every year, and it includes two time series for premiums and "administrative cost & net income". The reader can estimate the benefits time series by subtracting the latter from the former. Also, the annual Medicare and Social Security Trustees Reports were sources of their respective data.

Ten-year Treasury note open interest, trading volume, and deliveries annual data for 1982-2003 were originally obtained from the Chicago Board of Trade (CBOT). It was recently merged into the Chicago Mercantile Exchange (CME).

Estimating Hedging & Efficiency Gains: A two equations econometric simulation model was developed to estimate spread changes between income (premiums or taxes) and benefits for Medicare (Parts A & B but not D), Medicaid (combined federal and state), Social Security (OASDI), and private health insurance due to hedging the spread from 1982-2003 in hypothetical Medicare Part A FICA and benefits futures contracts.

The feasibility of hedging one variable in a futures contract for another variable is solely determined by a high correlation between the two variables or what the commodity markets like to call "cash and futures" markets. In this instance it was determined by a statistically significant regression coefficient between the levels of premiums and benefits on the one hand and the level of Part A FICA taxes and benefits on the other hand.[24]

- **Efficiency Gains**: Efficiency gains were measured by the combined, statistically significant regression coefficients on income and benefits in separate equations from simultaneous changes in trading volume, open interest, and futures contract deliveries. Analysis of the data in Figure 4 shows efficiency spread gains

[23] Kathleen M. Wong, The Jekyll and Hyde Act of Oncogenes, ScienceMatters@Berkeley, Volume 7, Issue 54, Story 3, June 2010.
[24] In an actual Medicare Part A FICA tax futures contract the trading unit would be FICA taxes per HI beneficiary. In these simulations just FICA taxes are used without loss of generality in order to more easily compare hedging results measured in billions of dollars with other cash flows also measured in billions of dollars.

increased from about $12.9 billions or 4 percent of total spread gains of about $409.1 billions in 1982 to about $241.9 billions or about 15 percent of $1,475.8 total spread gains in 2003.

- **Hedging Gains**: The model presumes the complexity science effect of hedging on private health insurance markets and related social insurance programs can be estimated in a similar but not exactly the same way the Solow growth residuals estimate total factor productivity in a macroeconomic growth accounting model. Growth equation residuals quantify the "total factor productivity" time series that is part of economic growth not explicitly accounted for by capital and labor in a macroeconomic model. Analysis of the data in Figure 4 shows hedging spread gains decreased from about 96 percent of total spread gains in 1982 to about 85 percent in 2003.

  Three or four intercept dummy variables (0,1 variables) are used to retrieve the time evolution of the hedging gains time series whose mean effect is embedded in the y-intercept term. Statistically, the intercept terms are the mean effects of all excluded variables in respective premiums and benefits equations. Intercept dummy variables in effect strip out the time evolution of one of possibly several excluded variables.

  Ex ante, there is no way to ascertain which one of the excluded variables has been retrieved from the intercept. To confirm that the retrieved premiums and benefits time series are plausible estimates of their respective hedging gains, the data must, at the very least, be analyzed to see if Prigogine's three requirements and other complexity science criteria were met.[25] If the time series are not in equilibrium before the complexity science dissipative structure is formed and is in equilibrium during, then this result is tentative evidence that dummy intercept model is producing theoretically plausible outcomes.[26]

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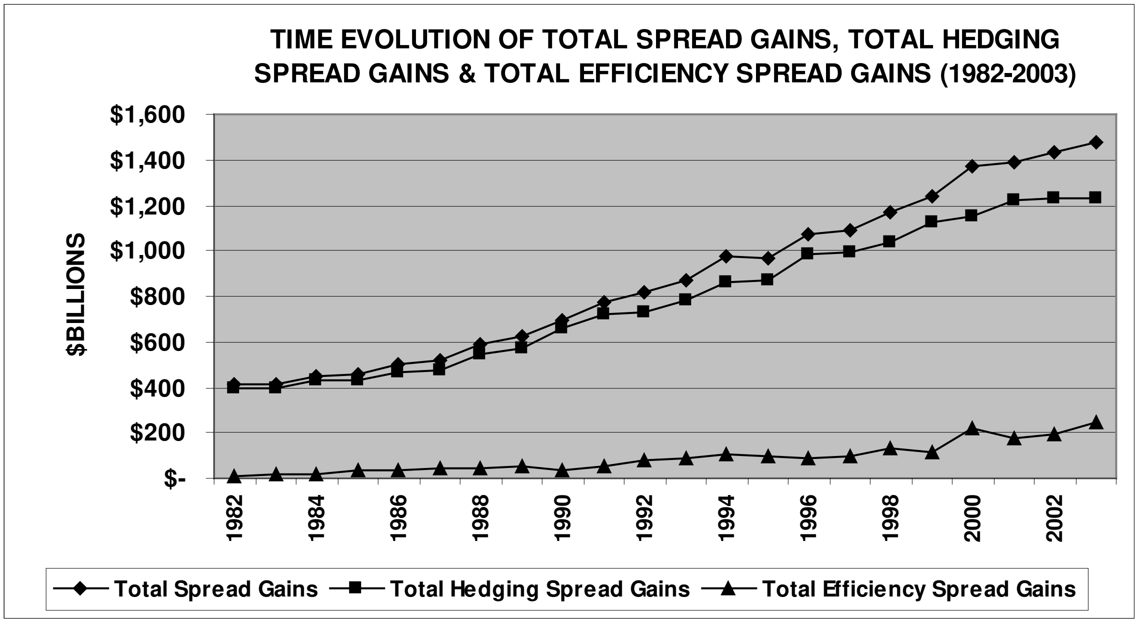
[25] This report is a *phenomenological* study of the emergence of dissipative structures during phase transitions. It "is used to describe a body of knowledge which relates empirical observations of phenomena to each other, in a way which is consistent with fundamental theory, but is not directly derived from theory" (Wikipedia, www.en.wikipedia.org/wiki/Phenomenology_(science)). A recent, well-known example of another phenomenological study was the two reports in the late 1990s that the expansion of the universe was accelerating, not decelerating as most physicists believed. Academics generally speculate that dark matter and dark energy explain this unexpected result, but there is no consensus on empirical proof for that speculation.

[26] The most important follow-up research project for these analyses is developing search algorithms to traverse systematically the state space of spread gains as potential hedging effects using intercept dummy variables. For all natural hedgers this report found both positive and negative spread gains were effects of hedging on income and benefits for health insurance and social insurance programs in the same state space. The empirical regularity was all long premium/tax futures and short benefits natural hedgers had opposite signs for intercept dummy variables compared to short premium/tax futures and long benefits natural hedgers. The reason why may lie with the speed of learning to hedge, but that will be left to be evaluated by a future paper.

FIGURE 4



The two equations model is estimated twice, first for governments/insurers (EQN 1 & 2) and then for employers/employees (EQN 3 & 4). The latter second equations are italicized. Also, the subscripts (x, t) on the income and benefits dependent variables indicate the x^{th} insurance market (private insurance), or social insurance program (HI FICA, SMI, Medicaid, and OASDI) in the t^{th} time period:[27]

EQN 1 & EQN 2: These spread change equations are for governments/insurers hedgers:

$$\text{Income}_{x,\,t} = \lambda_0 + \lambda_1 \text{ Dum 1} + \lambda_2 \text{ Dum 2} + \lambda_3 \text{ Dum 3} + \lambda_4 \text{ Dum 4} + \lambda_5 \text{ HI FICA}_t + \lambda_6 \text{ Open Interest}_t + \lambda_7 \text{ Volume}_t + \lambda_8 \text{ Deliveries}_t \qquad \textbf{EQN 1}$$

$$\text{Benefits}_{x,\,t} = \beta_0 - \beta_1 \text{ Dum 1} - \beta_2 \text{ Dum 2} - \beta_3 \text{ Dum 3} - \beta_4 \text{ Dum 4} + \beta_5 \text{ HI Ben}_t + \beta_6 \text{ Open Interest}_t + \beta_7 \text{ Volume}_t + \beta_8 \text{ Deliveries}_t \qquad \textbf{EQN 2}$$

EQN 3 & EQN 4: Spread change equations in italics are for hedged employers and employees:

$$Income_{x,\,t} = \lambda_0 + \lambda_1\, Dum\ 1 + \lambda_2\, Dum\ 2 + \lambda_3\, Dum\ 3 + \lambda_4\, Dum\ 4 + \lambda_5\, HI\ FICA_t + \lambda_6\, Open\ Interest_t + \lambda_7\, Volume_t + \lambda_8\, Deliveries_t \qquad \textbf{EQN 3}$$

$$Benefits_{x,\,t} = \beta_0 - \beta_1\, Dum\ 1 - \beta_2\, Dum\ 2 - \beta_3\, Dum\ 3 - \beta_4\, Dum\ 4 + \beta_5\, HI\ Ben_t + \beta_6\, Open\ Interest_t + \beta_7\, Volume_t + \beta_8\, Deliveries_t \qquad \textbf{EQN 4}$$

[27] The four non-italicized Dum variables will span all years for 1982-2003, but the four italicized *Dum* variables do not span the same years within that time period. The continuous variables Open Interest_t, Volume_t, and Deliveries are not changed going from the non-italicized to italicized equations. Sometimes lagged FICA and Ben variables were included to eliminate autocorrelation and improve statistical performance.

The time evolutions of the spread changes in the income equation with or without italics are step functions with the following steps:

$\mathrm{\lambda}_0, (\mathrm{\lambda}_0 + \mathrm{\lambda}_1), (\mathrm{\lambda}_0 + \mathrm{\lambda}_2), (\mathrm{\lambda}_0 + \mathrm{\lambda}_3)$, and $(\mathrm{\lambda}_0 + \mathrm{\lambda}_4)$ and italicized

$\lambda_0, (\lambda_0 + \lambda_1), (\lambda_0 + \lambda_2), (\lambda_0 + \lambda_3)$, *and* $(\lambda_0 + \lambda_4)$

The time evolutions of the spread changes in the benefits equation with or without italics are also step functions with the following steps:

$\mathrm{\beta}_0, (\mathrm{\beta}_0 - \mathrm{\beta}_1), (\mathrm{\beta}_0 - \mathrm{\beta}_2), (\mathrm{\beta}_0 - \mathrm{\beta}_3)$, and $(\mathrm{\beta}_0 - \mathrm{\beta}_4)$ and italicized

$\beta_0, (\beta_0 - \beta_1), (\beta_0 - \beta_2), (\beta_0 - \beta_3)$, *and* $(\beta_0 - \beta_4)$.

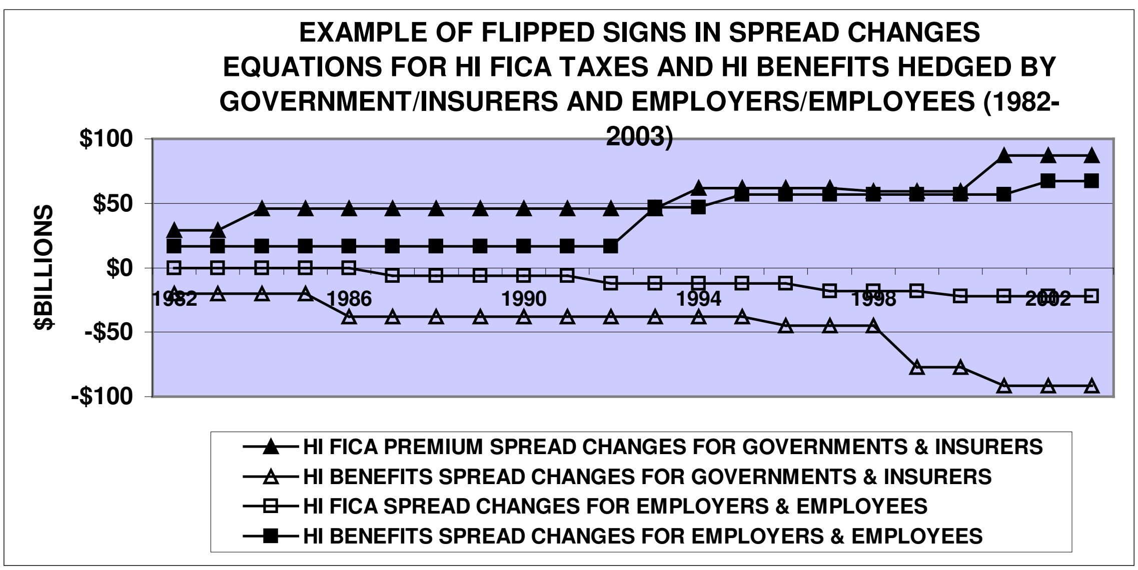
TABLE 2: NOMINAL, UNDISCOUNTED SPREAD GAINS BY MARKET AND SOCIAL INSURANCE PROGRAM 1982-2003 ($BILLIONS)

YEAR	HI MCARE	SMI MCARE	MCAID	PRIV INS	OASDI	TOTAL		M&M	TOT GOV
1982	$73.2	$27.0	$34.3	$2.9	$156.7	$294.0		$134.5	$291.2
1983	$74.6	$26.3	$34.3	$3.1	$157.5	$295.8		$135.2	$292.7
1984	$94.2	$26.4	$35.3	$37.3	$173.1	$366.3		$155.8	$328.9
1985	$97.4	$26.7	$36.7	$123.2	$174.3	$458.3		$160.8	$335.1
1986	$116.5	$26.7	$56.2	$124.0	$174.7	$498.1		$199.4	$374.1
1987	$127.3	$28.1	$56.9	$125.1	$177.3	$514.7		$212.3	$389.6
1988	$126.8	$29.1	$62.5	$163.9	$205.4	$587.8		$218.5	$423.9
1989	$130.9	$50.8	$68.4	$168.4	$206.6	$625.1		$250.1	$456.7
1990	$122.7	$48.9	$66.3	$226.3	$229.9	$694.1		$238.0	$467.9
1991	$133.4	$49.7	$96.8	$232.1	$262.7	$774.5		$279.8	$542.4
1992	$157.5	$43.2	$101.0	$237.4	$277.2	$816.3		$301.7	$578.9
1993	$194.6	$55.5	$103.4	$233.6	$282.0	$869.1		$353.5	$635.5
1994	$216.0	$62.5	$109.6	$291.9	$293.3	$973.2		$388.1	$681.4
1995	$217.1	$64.5	$107.7	$287.8	$289.0	$966.2		$389.3	$678.3
1996	$229.4	$75.2	$132.1	$342.2	$297.0	$1,076.0		$436.7	$733.8
1997	$243.2	$68.7	$132.7	$339.5	$302.5	$1,086.6		$444.7	$747.2
1998	$267.7	$83.7	$157.4	$342.5	$317.9	$1,169.2		$508.8	$826.7
1999	$290.5	$89.9	$157.7	$385.3	$315.8	$1,239.2		$538.1	$853.9
2000	$328.5	$103.8	$173.3	$420.2	$345.4	$1,371.2		$605.6	$951.0
2001	$350.6	$102.3	$184.2	$417.3	$337.3	$1,391.6		$637.1	$974.4
2002	$367.6	$100.8	$206.8	$413.1	$342.2	$1,430.6		$675.2	$1,017.4
2003	$386.6	$92.0	$237.3	$408.6	$351.3	$1,475.8		$715.9	$1,067.2
TOTAL	$4,346.3	$1,281.8	$2,350.8	$5,325.6	$5,669.2	$18,973.9		$7,979.0	$13,648.2
* M&M is the sum of the spread gains for Medicare (HI & SMI) and Medicaid programs. TOT GOV is the sum of M&M and OASDI.									

Estimates of spread gains based on Eqns 1-4 on this page are summarized in Table 2. The black triangle in Figure 5 is the positive HI FICA premium spread changes for governments and insurers, while the white rectangle is their negative HI benefits spread changes. Flipping the sign of the negative white triangle for HI benefits for governments/insurers to positive black rectangle gives the positive HI benefits for employers/employees. Flipping the sign of the positive black triangle for HI FICA for government/insurers to negative white rectangle gives the negative HI FICA for employers/employees.

To estimate the total spread gains for hedging HI FICA and HI benefits for both sets of natural hedgers, not including efficiency gains, add the absolute values of all four time series for each year. That total is about $3,270.7 billions for 1982-2003. Total HI spread gains for governments/insurers was about 68 percent of the total or about $2,225.4 billions, and spread gains for employers/employees was about 32 percent of the total or about $1,045.3 billions. Overall, governments/insurers also had higher total spread gains than employers/employees. However, spread gains for some social insurance programs governments/insurers and employers/employees were similar. While flipping of the signs of the spread changes always occurred, the reason why is not clear at this time.

FIGURE 5



SPREAD GAINS FINANCING FOR HEALTH & SOCIAL SECURITY

Spread Gains Financing for Health & Social Security (1982-2003): Table 3 summarizes the estimated first or second-order difference equation, theoretical solution equation to that difference equation based on its parameters, and the actual estimated solution equation for spread gains for each health and Social Security insurance market or social insurance program. The *Actual Solution* equations on the third line of the second column of Table 3 forecast the spread gains for 2009-2083. Present values of forecasts are used to estimate fiscal gaps. Table 4 summarizes mathematical and statistical properties that generate moving equilibria for the theoretical and actual solutions. The how and why of theoretical and actual solutions are explained in Technical Appendix B. Fiscal gap offsets discussed later are based on actual solutions equations.

TABLE 3: SPREAD GAINS MOVING EQUILIBRIA EQUATIONS FOR HEALTH & RETIREMENT ENTITLEMENT PROGRAMS & PRIVATE HEALTH INSURANCE 1984-2003 ($BILLIONS)

HI: Medicare Part A	1st Order Diff Eqn:	$Y_t - 0.997Y_{t-1} = 14.5$
	Theoretical Solution HI SG_t =	74.6 + 14.5(t)
	Actual Solution HI SG_t =	35.4 + 15.3(t)
SMI: Medicare Part B	1st Order Diff Eqn:	$Y_t - 0.846Y_{t-1} = 9.4$
	Theoretical Solution SMI SG_t =	26.3 + 9.4(t)
	Actual Solution SMI SG_t =	12.4 + 4.3(t)
MCARE: Medicare Parts A + B	1st Order Diff Eqn:	$Y_t - 0.963Y_{t-1} = 36.7$
	Theoretical Solution MCARE SG =	100.9 + 36.7(t)
	Actual Solution MCARE SG_t =	47.8 + 19.6(t)
MCAID: Medicaid (State & Federal)	2nd Order Diff Eqn:	$Y_t - 0.534Y_{t-1} - 0.540Y_{t-2} = 15.5$
	Theoretical Solution MCAID SG_t =	35.3 + 10.6(t)
	Actual Solution MCAID SG_t =	14.0 + 9.5(t)
M & M: MCARE + MCAID	2nd Order Diff Eqn:	$Y_t - 0.365Y_{t-1} - 0.682Y_{t-2} = 39.2$
	Theoretical Solution M & M SG_t =	155.8 + 24.0(t)
	Actual Solution M & M SG_t =	74.1 + 29.7(t)
PI: Private Insurance	1st Order Diff Eqn:	$Y_t - 0.935Y_{t-1} = 34.5$
	Theoretical Solution PI SG =	3.1 + 34.5(t)
	Actual Solution PI SG_t =	31.8 + 20.2(t)
OASDI: Social Security OASI + DI	2nd Order Diff Eqn:	$Y_t - 0..510Y_{t-1} - 0.350Y_{t-2} = 53.6$
	Theoretical Solution OASDI SG_t =	173.1 + 36.0(t)
	Actual Solution OASDI SG_t =	158.7 + 10.4(t)
TOT GOV: M & M + OASDI	2nd Order Diff Eqn:	$Y_t - 0.475Y_{t-1} - 0.583Y_{t-2} = 24.6$
	Theoretical Solution TOT GOV SG_t =	328.9 + 16.1(t)
	Actual Solution TOT GOV SG_t =	232.9 + 40.0(t)
TOT ALL: TOT GOV + PI	2nd Order Diff Eqn:	$Y_t - 0.597Y_{t-1} - 0.438Y_{t-2} = 45.0$
	Theoretical Solution TOT ALL SG_t =	449.2 + 32.1(t)
	Actual Solution TOT ALL SG_t =	312.0 + 58.2(t)

The first column of Table 4 lists the entities being analyzed. The second column is whether first or second-order difference equations were estimated for each entity. Columns 3 and 4 summarize statistical significance testing of first and second-order difference equations to ascertain the stability of their respective spread gains equations based on two criteria. The first criterion in Column 3 is the magnitude of the regression coefficients, and the second in Column 4 is the magnitude of eigenvalues. With respect to the first criteria Technical Appendix B shows that stability in part depends on $(-\beta_1 = -1)$ for first-order difference equations and depends on the magnitude of $(-(\beta_1 + \beta_2) = -1)$ for second-order difference equations. As for the second criteria, Technical Appendix B shows that stability also requires the only or dominant eigenvalues to equal one (E = 1).

TABLE 4: STATISTICAL ANALYSES OF SPREAD GAINS MOVING EQUILIBRIA (1982-2003)

ENTITY	1st or 2nd Diff Eqn?	1st Diff: $-\beta_1 = -1$? 2nd Diff: $-(\beta_1 + \beta_2) = -1$?	Eigenvalues (E) & Their Standard Errors (s_E)[28]	Start Year Dummy Variable
Priv Ins	1st	$-\beta_1 = -0.935$, $s_{\beta 1} = 0.045$ t-ratio = -1.444, 2-tail 90% critical value = -1.725	E = 0.935, $s_E = 0.045$ t-ratio = 1.444, 2-tail 90% critical value = 1.725	-
Medicaid	2nd	-0.534 – 0.540 = -1.074 t-ratio = -0.172, 2-tail 90% critical value = -1.753	E = 1.049, $s_E = 0.061$ t-ratio = 0.798, 2-tail 90% critical value = 2.132	2002
HI Medicare	1st	$-\beta_1 = -0.997$, $s_{\beta 1} = 0.036$ t-ratio = -0.083, 2-tail 90% critical value = -1.725	E = 0.997, $s_E = 0.036$ t-ratio = -0.083, 2-tail 90% critical value = 1.725	1991
SMI Medicare	1st	$-\beta_1 = -0.846$, $s_{\beta 1} = 0.112$ t-ratio = -1.375, 2-tail 90% critical value = -1.725	E = 0.846, $s_E = 0.112$ t-ratio = -1.375, 2-tail 90% critical value = 1.725	1998
Medicare	1st	$-\beta_1 = -0.963$, $s_{\beta 1} = 0.044$ t-ratio = -0.841, 2-tail 90% critical value = -1.725	E = 0.963, $s_E = 0.044$ t-ratio = -0.841, 2-tail 90% critical value = 1.725	1992
M & M	2nd	-0.365 – 0.682 = -1.047 t-ratio = -0.119, 2-tail 90% critical value = -1.753	E = 1.028, $s_E = 0.061$ t-ratio = 0.456, 2-tail 90% critical value = 2.132	1992
OASDI	2nd	-0.510 – 0.350 = -0.860 t-ratio = -0.347, 2-tail 90% critical value = -1.753	E = 0.899, $s_E = 0.061$ t-ratio = -1.644, 2-tail 90% critical value = 2.132	1988
TOT GOV	2nd	-0.475 – 0.583 = -1.058 t-ratio = -0.147, 2-tail 90% critical value = -1.746	E = 1.037, $s_E = 0.061$ t-ratio = 0.602, 2-tail 90% critical value = 2.132	-
TOT ALL	2nd	-0.597 – 0.438 = -1.035 t-ratio = -0.080, 2-tail 90% critical value = -1.746	E = 1.025, $s_E = 0.061$ t-ratio = 0.407, 2-tail 90% critical value = 2.132	-

If the two sets of criteria are met, then the solutions equations will be a moving equilibrium equation. In particular, it is a univariate function of time. All $(-\beta_1)$, $(-(\beta_1 + \beta_2))$, and eigenvalue (E) estimates were not statistically significantly different from one

[28] This paper uses the common convention that standard deviations of populations are denoted by σ_E and standard errors of samples are denoted by s_E.

(1) at the 10 percent or less level ($p \leq 0.10$) with appropriately specified degrees of freedom using small sample t-tests.

In first-order difference equations the regression coefficient for the lagged variable is the eigenvalue. The regression coefficient's standard error is the eigenvalue's standard error. In second-order difference equations the two regression coefficients are not eigenvalues. The quadratic equation must be used to solve for the two eigenvalues, and the larger of the two eigenvalues was tested for a statistically significant difference from one (1). The statistical significance of each of these five dominant eigenvalues was based on a simple t-test with the same sample standard error for the group sample of five dominant eigenvalues.

The fifth column was labeled *Start Year Dummy Variable*. As outlined in Technical Appendix B, the statistical significance of the intercept is necessary to formulate the solution to the difference equation. For six of the equations the initial regressions had intercepts that required an analysis of their time evolutions. For the entities for which a given year is specified, the year denotes when an intercept dummy variable caused the intercept variable to become statistically significant at the 10 percent or less level. That suggests that the intercept may be acting as an order parameter in a complexity science driven time evolution of the solution equation.

Figure 6 shows the spread gains as a percent of the combined value of premiums plus benefits for health insurance and the combined value of taxes plus benefits for the social insurance programs for 1982-2003. With the exception of HI Medicare, the entities relatively quickly settle into spread gains as a percent of combined income and outgo as a relatively constant 40-60 percent. Abruptly settling into significantly lower or higher new patterns are hallmarks of complexity science driven changes described by Jaynes and Horowitz & Smith.

HI Medicare spread gains settle into a range of about 100 percent or more of its combined HI FICA taxes plus HI benefits. Why HI Medicare spread gains should be about twice any of the other spread gains as a percent of their respective income plus benefits is not at all clear at this time. It could be a high value outlier from the search for plausible spread gains time evolutions or it could reflect something special about HI Medicare relative to the other estimated spread gains cash flows. It was not thrown out just because it was about twice the magnitude in percentage terms of the other spread gains cash flows. Even so, it will have to be studied further. The Bayesian inference steps recommended by Jaynes in his 'Macroscopic Prediction' paper were generally followed in this paper.

FIGURE 6

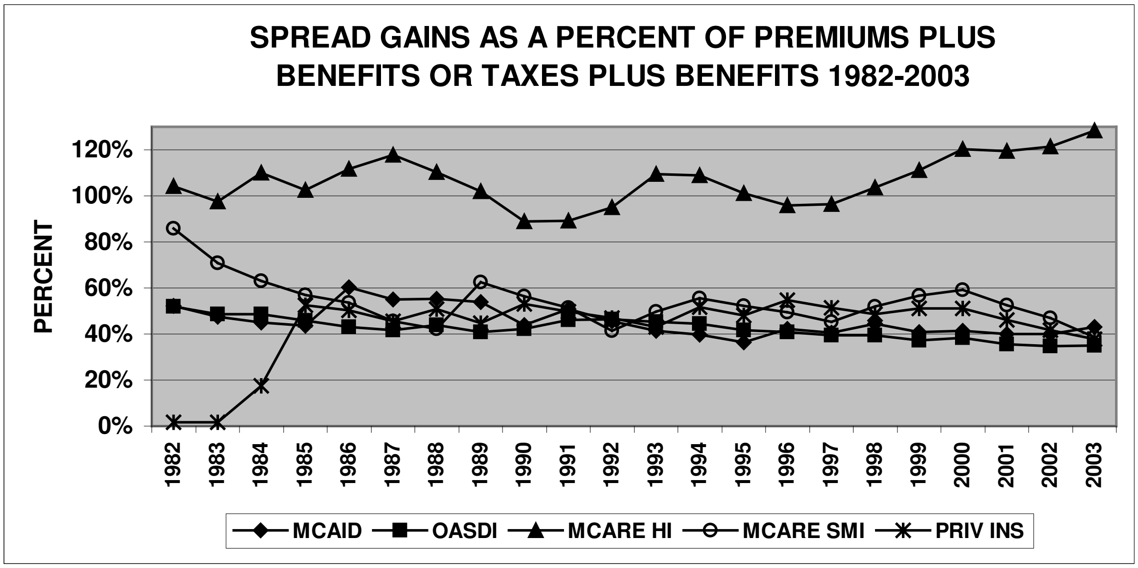


FIGURE 7

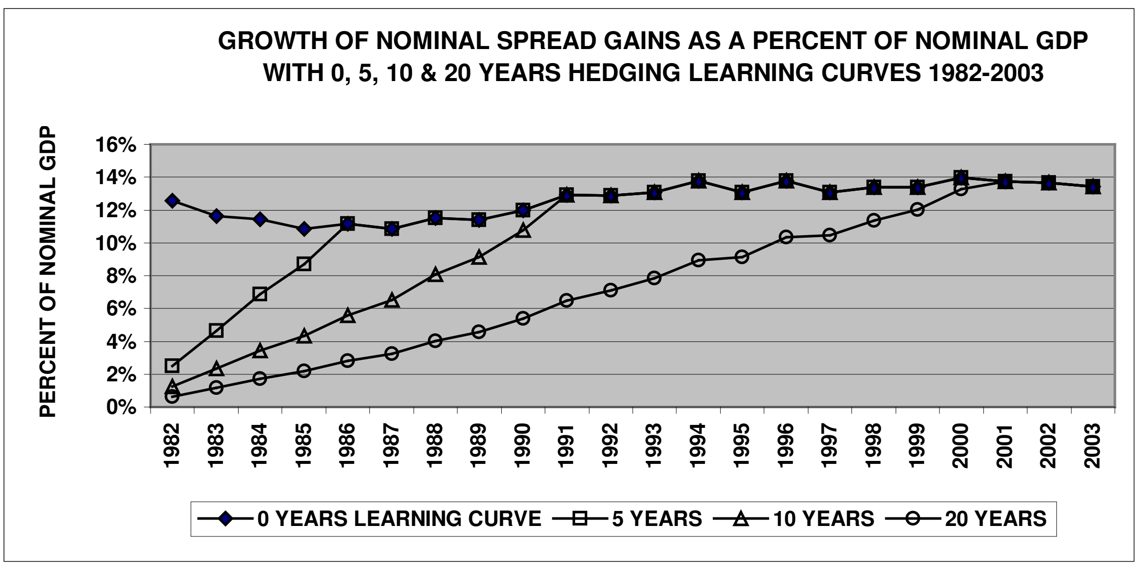


Figure 7 shows the effects of learning curves on the time evolution of nominal spread gains as a percent of nominal GDP for 1982-2003. Learning curves quantify how long it takes to hedge 100 percent of the hedgeable cash flows. The curves in Figure 7 are for 0, 5, 10, and 20 years learning curves. Since the annual spread gains as a percent of annual GDP is roughly constant at about 11-14 percent, the learning curves reduce by about half what the spread gains would have been for 5, 10, and 20 years.

Preliminary statistical simulation analyses using nominal historical data regressed current GDP on GDP lagged one year, current total spread gains, and a dummy slope variable for total spread gains for (1982-2003) with the following results:[29]

$$\underset{(p = .020)}{GDP_0 = 294.1} + \underset{(p \approx 0.0)}{0.901\ GDP_{-1}} + \underset{(p = 0.103)}{1.160\ Tot\ All_0} - \underset{(p = 0.101)}{0.355\ dum\ Tot\ All_0} \qquad \textbf{Eqn 5}$$

In general the statistical analyses in this paper used 10 percent significance cutoff levels. The preliminary estimate of the p-value for the regression coefficient for Tot All0 and the slope dummy are about 10 percent.

The economy grows by an amount about equal to the sum of the dissipative structures because a $1 billion increase in total spread gains increases GDP by about $1 billion, assuming constant coefficients. The time series of the increases in GDP due to Tot All spread gains is also a moving equilibrium with an eigenvalue not statistically different from one (1). The analysis suggests that hedging leads to the emergence of computational spread gains that in turn leads to an emergent real increase in GDP.

Spread Gains Financing of Health & Social Security (2009-2083): Tables 5-7 summarize spread gains financing of 75-year deficits. Figures 8-9 show key results from Tables 5-7 in graph form:

- **Table 5: Discounted Spread Gains Offsets To 75-Year Deficits For 2009-2083 (Trillions)**: These figures in trillions are based on the spread gains originally estimated for 1982-2003. They were then extended to begin in 2009 through 2083 using the moving equilibria spread gains equations that are linear functions of time. The 2009-2083 period is used because the CBO and other researchers estimated fiscal gaps for the 2009-2083 75-year period and subsequent rolling 75-year periods. A fiscal gap is the discounted unfunded Medicare, Medicaid, and OASDI obligations of the government divided by the discounted GDP for the same period. Discount rates range from 1 to 10 percent.
- **Table 6: *Spread Gains Fiscal Gap Offsets* Defined As Discounted Spread Gains As A Percent Of Discounted GDP 2009-2083**: The variable *spread gains fiscal gap offsets* are discounted spread gains divided by discounted GDP. They are measured as percentages that reduce fiscal gap percentages. Fox example, assume the gross fiscal gap is 8 percent and the spread gains offset is 5 percent. Then the net fiscal gap is 3 percent (8% - 5% = 3%). Spread gains fiscal gap offsets are calculated for Medicare (HI + SMI), Medicaid, Medicare + Medicaid (M & M), private insurance (Priv Ins), OASDI (Social Security & Disability Insurance), total health (Medicare + Medicaid + Priv Ins), total government (Tot Gov = M & M + OASDI), and total all (Tot All = Tot Gov + Priv Ins).

[29] The r-squared is 0.999, and the dummy slope variable for Tot All_0 is zero for the first two years. Starting the third year 1.160 is added to –0.355 for a net partial derivative of about 0.810. Both 1.160 and 0.810 are not statistically different from one (1.0). The standard error of the 1.160 regression coefficient is about 0.670. Subscripts on right hand side variables indicated the current and lagged time periods.

- **Table 7: *Spread Gains Fiscal Gap Offsets* As A Percent Of The 8% Midpoint Of CBO Adjusted Baseline Fiscal Gap 7-9 Percent Estimates For 2009-2083**: Using the hypothetical fiscal gap of 8 percent and a 5 percent fiscal gap offset in the previous bullet point, the latter reduces the former by 5/8 or 62.5 percent. Fiscal gap offsets as a percent of the midpoint of the CBO Adjusted Baseline are calculated just for Medicare, Medicaid, M & M, OASDI, and Tot Gov.

In Figure 8 a 3 percent discount rate for Tot Gov yields discounted spread gains of about $61.8 trillion (shown in Table 4). That's equal to a fiscal gap offset of about 7.8 percent (shown) in Table 6, in turn equal to about 97.6 percent of the 8 percent CBO midpoint (shown in Table 7). In discount rate terms the 3 percent rate is approximately equal to the breakeven point of financing nearly 100 percent of long-term government health and retirement unfunded obligations.

TABLE 5: DISCOUNTED SPREAD GAINS OFFSETS TO 75-YEAR DEFICITS FOR 2009-2083 (TRILLIONS)

DISCOUNT RATE	1%	2%	3%	4%	5%	6%	7%	8%	9%	10%
HI + SMI	$61.0	$41.2	$29.0	$21.3	$16.2	$12.7	$10.2	$8.5	$7.1	$6.1
MCAID	$29.1	$19.6	$13.8	$10.1	$7.7	$6.0	$4.9	$4.0	$3.4	$2.9
M & M	$90.1	$60.8	$42.8	$31.4	$23.9	$18.7	$15.1	$12.5	$10.5	$9.0
PRIV INS	$62.0	$41.8	$29.4	$21.5	$16.4	$12.8	$10.4	$8.5	$7.2	$6.1
TOT HEALTH	$152.1	$102.6	$72.2	$52.9	$40.2	$31.6	$25.5	$21.0	$17.7	$15.1
OASDI	$39.0	$26.6	$19.0	$14.1	$10.8	$8.6	$7.0	$5.8	$4.9	$4.2
TOT GOV	$129.1	$87.4	$61.8	$45.4	$34.7	$27.3	$22.1	$18.3	$15.4	$13.2
TOT ALL	$191.1	$129.2	$91.2	$67.0	$51.0	$40.1	$32.0	$26.8	$22.6	$19.3

TABLE 6: *SPREAD GAINS FISCAL GAP OFFSETS* & *NON-FISCAL GAP OFFSETS* DEFINED AS DISCOUNTED SPREAD GAINS AS A PERCENT OF DISCOUNTED GDP 2009-2083[30]

DISCOUNT RATE	1%	2%	3%	4%	5%	6%	7%	8%	9%	10%
HI + SMI	7.7%	5.2%	3.7%	2.7%	2.0%	1.6%	1.3%	1.1%	0.9%	0.8%
MCAID	3.7%	2.5%	1.8%	1.3%	1.0%	0.8%	0.6%	0.5%	0.4%	0.4%
M & M	11.4%	7.7%	5.4%	4.0%	3.0%	2.4%	1.9%	1.6%	1.3%	1.1%
PRIV INS	7.8%	5.3%	3.7%	2.7%	2.1%	1.6%	1.3%	1.1%	0.9%	0.8%
TOT HEALTH	19.2%	13.0%	9.1%	6.7%	5.1%	4.0%	3.2%	2.7%	2.2%	1.9%
OASDI	4.9%	3.4%	2.4%	1.8%	1.4%	1.1%	0.9%	0.7%	0.6%	0.5%
TOT GOV	16.3%	11.1%	7.8%	5.8%	4.4%	3.5%	2.8%	2.3%	2.0%	1.7%
TOT ALL	24.2%	16.3%	11.5%	8.5%	6.5%	5.1%	4.1%	3.4%	2.9%	2.4%

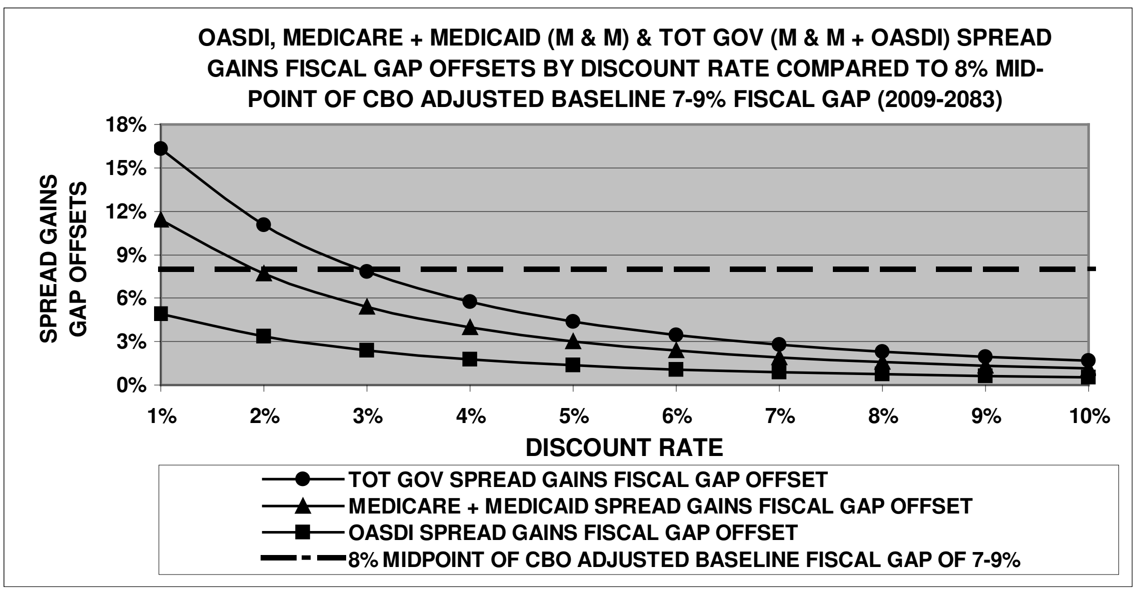
[30] *Spread Gains Fiscal Gap Offsets* apply just to Medicare, Medicaid, OASDI, and Tot Gov. *Spread gains Non-Fiscal Gap Offsets* apply to private insurance. Tot All is the sum of the Fiscal Gap Offsets and Non-Fiscal Gap Offset. It is not included in Table 7.

TABLE 7: *SPREAD GAINS FISCAL GAP OFFSETS* AS A PERCENT OF THE 8% MIDPOINT OF CBO ADJUSTED BASELINE FISCAL GAP 7-9 PERCENT ESTIMATES FOR 2009-2083

DISCOUNT RATE	1%	2%	3%	4%	5%	6%	7%	8%	9%	10%
HI + SMI	96.4%	65.0%	45.9%	33.6%	25.5%	20.1%	16.3%	13.4%	11.3%	9.6%
MCAID	46.0%	31.0%	21.9%	16.0%	12.1%	9.5%	7.6%	6.4%	5.4%	4.5%
M & M	142.4%	96.0%	67.6%	49.6%	37.8%	29.6%	23.9%	19.8%	16.6%	14.1%
OASDI	61.6%	42.0%	30.0%	22.3%	17.1%	13.5%	11.0%	9.1%	7.8%	6.6%
TOT GOV	204.0%	138.1%	97.6%	71.9%	54.8%	43.1%	34.9%	28.9%	24.4%	20.9%

Government actuaries estimate actuarial balances by discounting the Medicare HI and SMI programs at the "assumed rates of interest credited" to the respective trust funds. In 2009 the discount rates were, respectively, 5.0 and 4.4 percents. Subsequent fiscal gap estimates used a 5.7 percent discount rate for the period ending 2085.[31]

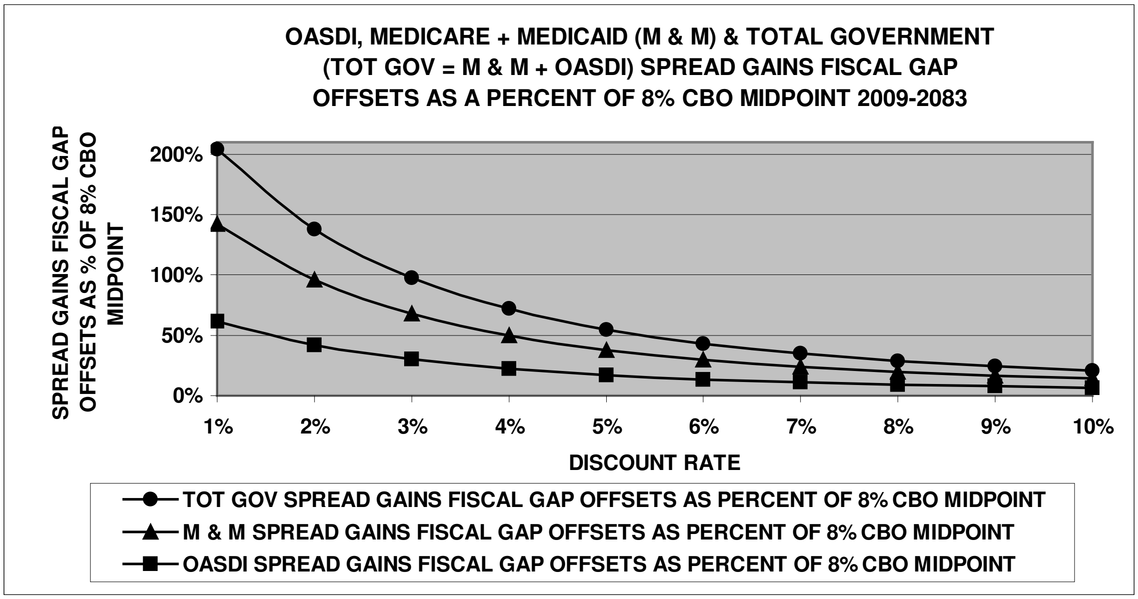
FIGURE 8



Let the discount rate for all fiscal gap offsets and non-fiscal gap offsets, for example, be 5 percent for (2009-2083). Then the Tot Gov spread gains discounted cash flow is about $34.7 trillions, and the Tot Gov spread gains fiscal gap offset is about 4.4 percent. M & M is about 3.0 percent and OASDI is about 1.4 percent of the 4.4 percent. Tables 5-7 were deliberately built to allow different discount rates for all entities.

[31] Medicare 2010 Trustees Report, pp. 78, 255 & 256. When revised for the period through 2085, Brookings researchers used a 5.7 percent discount rate to estimate the fiscal gap. Auerbach & Gale, 2010, "Déjà vu All Over Again: On the Dismal Prospects for the Federal Budget", p. 8.

FIGURE 9



CONCLUSIONS

Overview: The central assumption of this paper is when FFE income and benefits cash flows in private health insurance, Medicare (Parts A & B), Medicaid (combined state & federal), and Social Security OASDI (OASI & DI) are hedged, real or computational dissipative structures are turned on just as genes are turned on in biological development to trigger a phase transition.

Using historical data in econometric simulations suggested the collective dissipative cash flows partially offset all the income and benefits gradients by abruptly increasing GDP in the same year by an amount about equal to the annual sum of the dissipative income and benefits cash flows for that year. For 1982-2003 the collective offset was about 50 percent of the combined value of the annual incomes and benefits for all private health insurance markets and social insurance programs.

The dissipative structure cash flows equations mathematically and statistically were shown to be consistent with moving equilibria equations. In particular, the equations for the time evolutions for all cash flows considered collapsed to univariate functions of time. The simplicity of the equations allowed for a straightforward calculation of 75-year fiscal gap offsets to study the feasibility of financing very long term unfunded obligations for state and federal governments. Fiscal gaps are the present value of unfunded liabilities divided by the present value of GDP.

An 8 percent midpoint of the 7-9 Congressional Budget Office (CBO) estimates of fiscal gaps for 2009-2083 was compared to the dissipative structures also measured as fiscal gap offsets.

- At a 5 percent discount rate the fiscal gap offset from dissipative cash flows for Medicare, Medicaid, and Social Security was about 4.4 percent or about 55 percent of the 8 percent CBO midpoint. M & M (Medicare + Medicaid) offset was about 37.8 percent and OASDI was about 17.1 percent, respectively, of the 8.0 percent midpoint.
- At a 3 percent discount rate the Tot Gov fiscal gap offset was about 98 percent, M & M was about 68 percent, and OASDI was about 30 percent, respectively, of the 8.0 percent midpoint.

<u>The Promise of an Arab Spring Driven Health Care Reform</u>: What ostensibly recently began with the martyrdom of a single man in Tunisia led to the Arab Springs in Egypt, Libya, Syria, and other countries in the Middle East. Some governments collapsed; others teetered. But Arab Springs are the just the "creation of energy channels by means of phase transition[s]" discussed by Horowitz & Smith.[32]

An Arab Spring, world-wide, FFE health care reform initiative could be launched in 3-5 years at derivatives exchanges in financial capitals in the United States, Europe, and Asia.[33] The preliminary statistical analyses in this paper tentatively estimated that hedging virtually all health insurance markets and social insurance programs in the United States would increase annual nominal economic growth by about 11-14 percent. A less complete, slower launch would have slower economic growth.

Hedging health and retirement might be the best additional path for developed countries to prosperity. If it works, hedging would trigger a decrease in the severity of the pervasive debt crises of many developed countries. Ironically, in significant measure their debt crises sprang from their unfunded liabilities for social insurance programs.

Also, if time series of any measures of global health in underdeveloped economies are significantly FFE and are highly correlated with health care futures in the financial capitals, they can be partially financed by cross-hedging.

<u>Hedging Acts of Nature or God & Hedging Public Policy</u>: High correlations between other health and retirement cash flows and Medicare Part A tax and benefits cash flows are essential to launching these first-generation health futures markets. But the debut of Medicare FICA and benefits futures contracts should be seen in a broader landscape of not just hedging health and retirement cash flows and untoward acts of God or nature that destroy crops but also hedging "public policy".

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[32] Op cit, p. 5.
[33] It is important to point out that the recent debacle in financial markets in the United States over "derivatives" occurred in over-the-counter (OTC) derivatives that included the now famous credit default swaps. The derivatives trading proposal in this paper emphasizes exchange-traded derivatives. To the author's knowledge there were no defaults in any *exchange-traded derivatives* including currencies and interest rate instruments during this time. All derivatives are just insurance policies that are usually carefully designed to monetize various measures of risk by trading them. In financial terms the process of quantifying new specific measures of risk to be traded is called intermediation.

Hedging Medicare first and now, based on complexity science principles, in time will lead to hedging macroeconomic fiscal and monetary aggregates like taxes, GDP, and money supply in the United States and around the world. Hedging will also help finance affordable congressional and state legislation. Hedging our nation's annual federal budget is no different than hedging expected agricultural crop yields.

The door to hedging public policy began to swing open in the 1970s with the publication in the *Journal of Political Economy* (JPE) of the Black Scholes option pricing model and the nearly simultaneous launch of exchange-traded currency and interest rate futures in Chicago.

Now the Chicago Mercantile Exchange (CME) has already modestly started trading derivatives on government news releases of various measures of economic activity such as non-farm payroll. The trading market is called *Economic Event*. Start hedging health and retirement in the United States, and we'll witness a world-wide expansion of exchange-traded derivatives financing of government.

TECHNICAL APPENDIX A: BRIEF SUMMARY OF SPREAD HEDGING COMPONENTS

Efficiency Gains: Efficiency gains are the combined effects, if any, of changes in trading volume, open interest, and deliveries on premiums and benefits. Commodity markets use words like *efficiency gains* to describe the effects of increased trading volume, open interest, and deliveries on the bid-ask spread or other measures of increased efficiency. In this study open interest and trading volume are almost always statistically significant, although their signs sometime switch. Deliveries are not statistically significant as often. Efficiency gains can have positive or negative effects on a gradient:

- $P_{e,t}$ = premiums efficiency gains at time t **Eqn A-1**
- $B_{e,t}$ = benefits efficiency gains at time t. **Eqn A-2**

Hedging Gains: Hedging gains can be positive or negative for premiums or benefits:

- $P_{h,t}$ = premiums hedging gains at time t **Eqn A-3**
- $B_{h,t}$ = benefits hedging gains at time t. **Eqn A-4**

Economic Gains: Premiums and benefits economic gains are the sums of their respective efficiency and hedging gains:

- $(P_{h,t} + P_{e,t})$ = premiums economic gains (hedging + efficiency) at time t **Eqn A-5**
- $(B_{h,t} + B_{e,t})$ = benefits economic gains (hedging + efficiency) at time t. **Eqn A-6**

Spread Gains: For governments and insurers spread gains are the *difference* between premium economic gains and benefits economic gains. Positive spread gains are realized when simultaneously hedging premiums and benefits increases their spread:[34]

- $SG_t = (P_{h,t} + P_{e,t}) - (B_{h,t} + B_{e,t})$ = spread gains at time t **Eqn A-7**
- $S_{f,t} = S_{i,t} + SG_t = (P_t + P_{h,t} + P_{e,t}) - (B_t + B_{h,t} + B_{e,t})$ = time t final spread **Eqn A-8**

All the individual terms in $(P_{h,t} + P_{e,t})$ and $(B_{h,t} + B_{e,t})$ in principle can be negative or positive. In practice usually $(P_{h,t} + P_{e,t})$ is positive, and usually $(B_{h,t} + B_{e,t})$ is negative $(- B_{h,t} - B_{e,t})$ for governments and insurers. Consequently, when a negative $(B_{h,t} + B_{e,t})$ is subtracted from a positive $(P_{h,t} + P_{e,t})$, the result is an even larger positive number. Spread gains for governments and insurers at time t can be rewritten as:

- $SG_t = (P_{h,t} + P_{e,t}) - (- B_{h,t} - B_{e,t}) = (P_{h,t} + P_{e,t} + B_{h,t} + B_{e,t})$. **Eqn A- 9**

[34] See the discussion on pages 18-19 for how these formulas change when they are applied to employees and employers. The signs of these equations are reversed or "flipped".

TECHNICAL APPENDIX B: MODELING STABILITY IN HEALTH & SOCIAL SECURITY SPREAD GAINS CASH FLOWS

Eigenvalues must be estimated to ascertain stability in insurance markets and social insurance programs during simulated hedging. Spread gains for insurance, Medicare, and Social Security had eigenvalues that were not statistically significantly different from one (1). The importance of eigenvalues not being statistically significantly different from one (1), together with other statistical results discussed below, is the possibility that spread gains series for all health insurance and entitlement programs have *moving equilibria* general solutions. If so, the results are consistent with Prigogine's claim that new, stable dissipative structures are part of an increasingly ordered space-time structure.

The organization of this Technical Appendix B is first a brief review of estimating eigenvalues, and then an analysis of moving equilibria in social insurance programs that was labeled Tot Gov in preceding pages. An analysis of moving equilibria paves the way to showing how and how much hedging entitlement programs can pay for very long-dated macroeconomic deficits measured in fiscal gap terms.

Estimating Second-Order Difference Equation Eigenvalues for Moving Equilibria: Several but not all private health insurance markets and social insurance programs can be modeled by second-order difference equations. The reason in part is due to actuaries who routinely use 18 months old or older historical data to help them estimate future premiums and benefits.

The basic form of the second-order difference regression equation for statistically estimating its two eigenvalues is Eqn B-1:

$$Y_t = \beta_0 + \beta_1 Y_{t-1} + \beta_2 Y_{t-2}. \qquad \textbf{Eqn B-1}$$

It can be rearranged as a homogeneous equation with a non-zero constant on the right-hand-side of Eqn B-2:

$$Y_t - \beta_1 Y_{t-1} - \beta_2 Y_{t-2} = \beta_0. \qquad \textbf{Eqn B-2}$$

The two regression coefficients on the left-hand side of the equation (β_1 & β_2) of Eqn B-2 are then inserted into the following characteristic equation. The two roots (sometimes denoted by b_1 & b_2) of Eqn B-3 are the eigenvalues:

$$b_1, b_2 = ((-\beta_1 \pm (\beta_1^2 - 4(-\beta_2))^{½})/2). \qquad \textbf{Eqn B-3}$$

The two eigenvalues (b_1 & b_2) are then used to construct the *complementary function*, which is the deviation from equilibrium in the general solution, defined in Eqn B-4:

$$A_1(b_1)^t + A_2(b_2)^t, \qquad \textbf{Eqn B-4}$$

A_1 and A_2 are definitizing coefficients based on the first two values of the time series for the second-order difference equation. The constant term β_0 (in addition to β_1 and β_2) is used to calculate the *particular integral* or equilibrium.[35] The general solution to the second-order difference equation is the sum of the complementary function (deviation from equilibrium) and the particular integral (equilibrium).

<u>Spread Gains Eigenvalues Are Not Statistically Significantly Different from One</u>: The two Tot Gov eigenvalues estimates are ($b_1 = 1.037$) and ($b_2 = -0.562$), so the complementary function (Eqn B-5) is

$$Y_c = A_1(1.037)^t + A_2(-0.562)^t . \qquad \textbf{Eqn B-5}$$

The limit of the second term in Eqn B-5 is zero because the absolute value of a number less than one raised to successively higher integer values approaches zero. Also, if ($b_1 = 1.037$) is not statistically different from one, then it is replaced by ($b_1 = 1.000$) and $A_1(1.037)^t$ becomes $A_1(1.000)^t$, which simplifies to just A_1, thereby definitizing $A_1 = Y_0$.

<u>Mathematical Requirements for Moving Equilibrium</u>: When the sum of the regression coefficients in Eqn B-2 is not equal to minus 1 as shown in Eqn B-6, then the

$$(\beta_1 + \beta_2) \neq -1 \qquad \textbf{Eqn B-6}$$

particular integral equation (Y_p) that specifies a fixed equilibrium[36] is Eqn B-7:

$$Y_p = (\beta_0) / (1 + \beta_1 + \beta_2). \qquad \textbf{Eqn B-7}$$

However, when the sum of the regression coefficients in Eqn B-6 is not statistically, significantly different from minus one (–1), the denominator of Eqn B-7 is about zero. If so, it has to be rewritten as Eqn B-8 for a particular integral of a *moving equilibrium*:[37]

$$Y_p = (\beta_0 / (\beta_1 + 2))t. \qquad \textbf{Eqn B-8}$$

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[35] See chapter 17 in <u>Fundamental Methods of Mathematical Economics</u> (2nd ed) by Alpha C. Chiang, McGraw Hill Book Company, 1974 for a discussion of eigenvalues estimation. Also, eigenvalues have a sampling distribution and a standard error.

[36] See Chiang, pp. 579-580 (1974) for examples and explanation. In Chang the notation of c for constant and a_1 and a_2 for the regression coefficients were replaced, respectively, by β_0, β_1, and β_2, where appropriate.

[37] See Chiang, p. 580.

General Solutions Equations for Stable & Unstable Spreads in Tot Gov Social Insurance Programs: If spread gains in Tot Gov (social insurance programs) were stable with a fixed equilibrium, then the general solution equation would have been Eqn B-9 with the absolute values of b_1 and b_2 less than one. If spreads gains in Tot Gov were a moving equilibrium, the general solution equation would be Eqn B-10 with the absolute value of b_1 not statistically significantly different from one.

$$Y_t = [A_1(b_1)^t + A_2(b_2)^t] + [\beta_0 / (1 + \beta_1 + \beta_2)]. \quad \textbf{Eqn B-9}$$

$$Y_t = Y_c + Y_p = A_1 + (\beta_0 / (\beta_1 + 2))t . \quad \textbf{Eqn B-10}$$

Spread Gains Are a Linear Function of Time: The only variable in Eqn B-10 is time (t). Three mathematical considerations unexpectedly and simultaneously conspire to make the general solution of the second-order difference equation for spread gains a linear function of time:

- The sum of β_1 and β_2 from Eqn B-2 was not statistically significantly different from minus one. That is a precondition for rejecting a fixed equilibrium model and testing for a moving equilibrium model.

- The dominant eigenvalue was not statistically significantly different from plus one. That is a precondition for a moving equilibrium.

- The constant in the second-order difference equation was statistically significant, which made the particular integral a function of time (t), given the moving equilibrium just described. β_0 is the only constant in the numerator of the coefficient of (t) in Eqn B-10. If β_0 were zero, the coefficient would be zero.

For example, when the values of the first datum A_1 in the time series and the two regression coefficients β_0 & β_1 are put into Eqn B-10, the prediction of the mathematical model for TOT GOV SG_t is Eqn B-11 for t = 3, ..., n for 1984-2003:

$$\text{TOT GOV } SG_t = Y_t = 328.9 + 16.1\ (t). \quad \textbf{Eqn B-11}$$

Fitting an OLS statistical straight line to the TOT GOV SG_t actual data for 1984-2003 is Eqn B-12. All Actual Solution equations in Table 3 are based on fitted spread gains:

$$\text{TOT GOV } SG_t = Y_t = 232.9 + 40.0\ (t). \quad \textbf{Eqn B-12}$$

Estimating First-Order Difference Equation Eigenvalues & Moving Equilibria: Details of the estimation of eigenvalues and moving equilibria for first-order difference equations largely follow the preceding material for second-order difference equations. They are summarized here, and additional details are in Chiang.

The general form of the particular integral for a first-order difference equation is:

$$Yp = \beta_0 / (1 + \beta_1). \qquad \textbf{Eqn B-13}$$

Recall the convention that a positive β_1 is on the right-hand side of the equal sign and negative on the left-hand side and that Eqn B-13 uses the left-hand-side sign practice. β_1 (which coincidentally is the eigenvalue) cannot be negative one (-1) and still use Eqn B-13. Just like the case for second-order difference equations, an alternative must be specified. The particular integral becomes Eqn B-14 and the general solution becomes Eqn B-15. Again, the general solution becomes a univariate function of time, just as it was for second-order difference equations:

$$Y_p = \beta_0\, t \qquad \textbf{Eqn B-14}$$

$$Y_t = Y_0 + \beta_0\, t. \qquad \textbf{Eqn B-15}$$

<u>**Estimating Fiscal Gap Offsets**</u>: The 75-year fiscal gap offset (FGO) percent is just the present value (PV) of Eqn B-15 for first-order difference equations or Eqn B-10 for second-order difference equations divided by the present value (PV) of GDP for the same time period. Estimates of present value GDPs are available in recent annual Medicare <u>Trustee Reports</u>. For Tot Gov for (2009-2083) the general FGO equation is Eqn B-16, and the specific FGO equation is Eqn B-17:

$$FGO_{Tot\ Gov} = (PV\ Tot\ Gov)/\ (PV\ GDP) \qquad \textbf{Eqn B-16}$$

$$FGO_{Tot\ Gov} = \sum_{t}\ [\ (232.9 + 40.0\ (t))/(1 + r)\text{^}t\ ]\ /\ \ (PV\ GDP), \qquad \textbf{Eqn B-17}$$

$t = 1, 2, \ldots, 75.$

where r = discount rate.

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