Saving Capitalism from Finance

Using "Entropy Economics" to Dispel the Darkness

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Because an economy resembles an engine, we introduce thermo-economics.
Successfully to compare an economy to an engine, we need "thermodynamic literacy".

Testimonials in support of thermodynamic literacy:
(Economists especially, please note:) ☺

Robert Wolf PhD, Emeritus Professor of Physics, Harvey Mudd College, Claremont, CA

> "Thermodynamics provides a similar basic framework of statistical understanding for physics, engineering, and economics, as evolution provides for biology."

Albert Einstein, quoted in M.J. Klein, *Thermodynamics in Einstein's Universe*, in Science, 157 (1967), p. 509.

> [A law] is more impressive the greater the simplicity of its premises, the more different are the kinds of things it relates, and the more extended its range of applicability. Therefore, the deep impression which classical thermodynamics made on me. It is the only physical theory of universal content, which I am convinced, that within the framework of applicability of its basic concepts will never be overthrown.

Sir Arthur Stanley Eddington, in *The Nature of the Physical World*. Macmillan, New York, 1948, p. 74.

> The law that entropy always increases -- the second law of thermodynamics -- holds I think, the supreme position among the laws of Nature. If someone points out to you that your pet theory of the universe is in disagreement with Maxwell's equations - then so much worse for Maxwell equations. If it is found to be contradicted by observation - well these experimentalists do bungle things sometimes. But if your theory is found to be against the second law of Thermodynamics, I can give you no hope; there is nothing for it but to collapse in deepest humiliation.

Table of Contents

Foreword

Saving Capitalism from Finance:

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A financial bubble burst in 2008, and our economy fell close to ruin. Deficit, federal spending averted catastrophe, but alienated many in the public who perceived the spending to reward culprits, and/or to herald socialism. No trusted scientific model existed either to guide repair to the system, or to frame explanation to the public.

Without valid science, finance reform can only be political, leaving greed free to trump sense. Progress in economic science requires its reconciliation with the greatest of nature's laws: the Second Law of Thermodynamics, the "entropy law". The following quotations fairly state our premise:

> "*The fact that there are no known exceptions to the laws of thermodynamics should be incorporated into the axiomatic foundation of economics.*"[1]
>
> *"Classical economics was built largely on the analogy to [Newtonian] mechanics, as it was known in the time of Adam Smith, particularly the idea of mechanical equilibrium. But a macroeconomic system is in some ways more like a thermodynamic system than a mechanical one, so we develop that analogy. ... We conjecture that [the fundamentality of entropy to physics] may [also] be true in economics; the direction of economic change may have as much to do with [entropy] as with any of the other ... factors ..."* (Jaynes, 1991).

Attempts to reconcile economics and thermodynamics have not yet succeeded. Some have postulated -– others have dismissed -– the mathematical isomorphism of entropy and money. None however has commented on the mathematical isomorphism of increasing entropy with increasing profit and money supply.

Most people are not familiar with increasing entropy, so we include a physics-for-poets explanation. Even a simplified rendering opens a door to careful and novel, economic thought.

Entropy Economics calls for new rules of fair play, but not for socialist "central planning". One cannot plan a baseball game, but one can umpire it. The more violent is a sport, the more it needs regulation. Economics is a blood sport.

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Our motto: *This project would never have happened if we had the time to do it*. (AJ)

[1] Underwood, D. and King, P. (1989) "On the Ideological Foundations of Environmental Policy" *Ecological Economics* 1: 324.

Saving Capitalism from Finance

Using Entropy Economics™ to Dispel the Darkness

By Richard Goldwater and Arthur Jonath

Profit and Entropy Release 11.0.1[2]

"Capitalism is the extraordinary belief that the nastiest of men, for the nastiest of reasons, will somehow work for the benefit of us all."[3]

Part I: *Isaac Newton and the Necessity of "Entropy Economics"*

Correspondence with Nature

Analogy presents our case. Analogic thinking in science is governed imagination, not poetic license. We find analogy between increasing entropy and profit; mathematics adapted from thermodynamics supports this idea.

Cultures create characteristic analogies from perceptions of nature. Traditional analogy is metaphorical or symbolic. Greek myths organized stars into constellations. Shakespeare's characters saw portents of meaning in comets and lightning. People still consult astrologers, and attribute intentionality to nature, as if disease punishes sin, or as if it rains to ruin a picnic.

> "Physicists often like to argue by analogy, on the 'parsimony principle' that there are not that many fundamentally different phenomena.[4]

Social sciences have developed as analogies of physical science. As they have, perception of human as well as of physical nature has become increasingly mathematical and statistical. We accept evidence for biological evolution rather than bow to religious dogma. We calculate the effects of tobacco on health and of seatbelts on safety, and use the results to educate behavior and inform policy. We dispense medical treatment by algorithm rather than by educated compassion. We invent cognitive and neurosciences to study the brain and bypass "the mind".

Adam Smith and his followers have associated the social science of economics with Newton's Laws of Motion by using mathematical models consistent with them.[5] There was no other scientific, mathematical model from which to analogize. Newton's Third Law, that "every action has an equal and opposite reaction" appears as the law of supply and demand, the basis of the idea of the Free Market. Smith described an economy as self-regulating, as though by an "invisible hand." This hand is no mystery. Smith's economics effectively compares an economy to a gyroscope, a spinning mechanism that Newton's invisible laws "keep" in balance.

"Isomorphism" is an especially rigorous kind of analogy, implying a precise mapping of properties or functions from "A" to "B". This is all very well when referring to identical biological structures or to mathematical theorems. The question arises across different domains: if their math is the same, are they the same?

If the mathematics of present economics is the same as applies to Newton's physical universe of the 17th Century, does this make economics Newtonian physics? Can one expect numbers of dollars to behave like objects and forces, because forces and objects behave like numbers? Whether they know it or not, *economists assume that they do*. Otherwise, mathematical econom-

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2 The authors are grateful for the invaluable assistance of Benjamin Lambert and Richard Kullberg.

3 Attributed to economist John Maynard Keynes

4 (Credited to Richard Feynman)

5 Don't just take our word for it. "Isaac Newton's Influence on Adam Smith's Natural Laws in Economics", Norriss S. Hetherington, *Journal of the History of Ideas*, Vol. 44, No. 3 (Jul. - Sep., 1983), pp. 497-505, University of Pennsylvania Press

ics could claim no power to explain.

Using fancy mathematics to describe events does not confer automatic validity. Economists ignore that the Second Law of Thermodynamics, the "entropy law" in the 19th Century revised physical science.

Science since the 19th Century expands and extends, but does not replace or refute the thermo-economics that we introduce here. We shall be content if this document advances economic thought from the 17th to the 19th century.

As we did by writing this monograph, we hope that by reading it you will learn enough about entropy and profit to understand the necessity of "entropy economics".

Newton's Third Law versus the Second Law of Thermodynamics

Newton's Laws of Motion and the Laws of Thermodynamics may compete or combine to describe our world. Newton's *Third Law* and the thermodynamic *Second Law* are especially important. We seek an economic theory that may unify them.

Newton's laws are zero-sum. Overall, nothing changes; all is conserved. Forces of motion balance each other; the future is perfectly predictable. Newton's *Third Law* has it that "every action produces a simultaneous, equal and opposite reaction".

The Second Law of Thermodynamics is the only universal, *non zero-sum principle*. It describes events as new and unrepeatable, but not because physical events are "creatively original". Physical events use up fuel, waste energy and leave a mess.

Entropy is the quantity that accounts for used-up fuel and wasted energy. We may not like it, but increasing entropy represents the irreversible "arrow of time". There is more time today and there is more entropy today than there were yesterday.

Newtonian science is overall, zero-sum. Anything zero-sum overall is Newtonian. Thermodynamic science is overall, not zero-sum. Anything overall not zero-sum increases entropy.

Those among us who are "scientifically challenged" may best distinguish Newtonian from thermodynamic science as "*action-and-reaction*" versus "*cause-and-effect*". A rifle recoils *at the same time as* a bullet flies away. This is symmetrical, instantaneous, and zero-sum, action-and-reaction. Gunpowder ignites *before* a bullet flies away. This is asymmetrical and sequential, cause preceding-and-producing a new effect.[6] Newtonian laws offer perfect predictability. Thermodynamics is a roll of the dice.

From the Success of Newtonian Mechanics to the Failure of Newtonian Economics

Isaac Newton wrote in the late 1600s. Adam Smith, father of mathematical economics, published Wealth of Nations in 1776. Smith inferred his ideas from Newton's zero-sum laws, the only scientific "game in town" at the time. Present day economics is consistent with Newtonian science and math. Thermodynamic pioneers wrote during the 19th century. Neither Smith nor Newton could have known about thermodynamics or increasing entropy.

Isaac Newton described the universe as a mechanism – as a friction-free, perfectly efficient *mechanism* of forces in perfect balance and planets in perpetual motion. So, one speaks of Newtonian mechanism and of Newtonian "*mechanics*".

Perfect balance means that Newton's laws are zero-sum, which means "no net change". Newton's laws work "forward" as well as "backward". The laws care not if the apple falls to earth, or if the earth comes up to meet the apple. Newton's Third Law is an especially salient example of

[6] Some readers may wonder as contemporaneous scientists did, how to reconcile reversible, Newtonian and irreversible thermodynamic theories. The "Boltzmann Interpretation" did just that. Although few have acknowledged it, in one fell swoop, Boltzmann opened the door of the industrial age to admit the future spirits of the Atomic Age, and of its successor, the Information Age. As we may now be approaching the cautionary Age of Entropy, we shall not leave this document without glancing at what Boltzmann wrought.

Newtonian zero-sumness: "Every action has a simultaneous, equal and opposite reaction". Since they are simultaneous and zero-sum, it matters not which is "action" and which is "reaction".

A child's see-saw is zero-sum; as one side goes up, the other goes down. Sporting events are zero-sum. A winning team goes up one and the other goes down one game in the league standings; +1,-1 add to zero. A barter system is zero-sum; a horse and a cow in a trade may change places, but overall, nothing has changed.

Economics as inherited from Adam Smith is zero-sum.[7] The Law of Supply and Demand recapitulates Newton's Third Law; there is no other natural analogy to support that a law of supply and demand applies. Supply and demand are presumed to affect each other like a see-saw. Neither is necessarily a cause or an effect; supply goes down or demand goes up, and prices go up. Supply goes up or demand goes down, and prices go down. *Stable price represents an ideal equilibrium between supply and demand as action and reaction*.

Generalized from individual transactions, Smith's theories are known as "microeconomics". In the 20th Century, John Maynard Keynes presented vital, new theories of an integrated economy. Keynes also relied on a zero-sum model. His "macroeconomics" addressed huge quantities like aggregate supply/demand and Gross National Product. To balance full employment against inflation or deflation, Keynes argued that government spending must be increased or decreased in response to changes in other parts of the formula. In Keynes as well as in Smith, balance is all.

Historian Robert Nadeau describes how economics developed after Adam Smith:[8]

> *The progenitors of neoclassical economics, all of whom were trained as engineers,[9] developed their theories by substituting…variables derived from classical economics for physical variables in the equations of soon-to-be outmoded, mid-19th century…physics.*

Economist H. Eugene Stanley discusses "econophysics", his term.[10] Stanley's team recently analyzed more pricing data than ever before. They discovered that the well-known physical Power Law that predicts earthquakes could also predict "once in a century" economic "tsunamis" within an error band currently acceptable to monitor earthquakes. Such room for error makes economic predictions not very useful.

Accepted mathematical formulations are at last suspect. Nouriel Roubini writes, "*Laissez-Faire Capitalism Has Failed*".[11] Conservative guru Alan Greenspan publicly laments the failure of his economic thinking.[12] Notable businesspeople including George Soros call for a new economic model.[13] The *Financial Times* hits "misplaced risks":

> *We are surrounded by things that do not work well, but [that] are nonetheless widely used. …[including] according to Nassim Nicholas Taleb, …the Black-Scholes model. The equation, named after…the men who devised it in 1973, is widely seen as the best method for pricing options and the derivatives based on them. It is often argued that Black-Scholes has provided the basis for the explosion of derivatives trading over the past two decades.*
> *Mr. Taleb, a controversial mathematical trader and author of* Fooled by Randomness *and* The Black Swan*, thinks the fundamentals of the equation are plain wrong, that it is not used in practice, and that the revered status of its founders, who were given the Nobel Prize, is undeserved.*[14]

Economists have believed that their pricing models were 99% correct, and called rare events, "outliers". Since no theory pertained to them, economists could reason with perfect circu-

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7 Don't just take our word for it. Op. cit.
8 "The Economist Has No Clothes", by Robert Nadeau; *Scientific American*, March 2008
9 Among them were William Jevons, August Walras, Francis Edgeworth, and Vilfredo Pareto.
10 Econophysics and the Current Turmoil. H. Eugene Stanley, PhD. Physics: the Back Page. Dec 2008. Vol. 17, #11
11 Forbes Magazine, February 19, 2009
12 Alan Greenspan Oct 23, 2008, op. cit.
18 George Soros, "The Crisis & What to Do About It", New York Review of Books, Vol. 55, No. 19, December 4, 2008.
14 "Mispriced Risk Tests Market Faith in a Prized Formula", Anuj Gangahar, *Financial Times*, April 15, 2008.

larity that "outliers" were of no concern.[15] Their reasoning reigned until supercomputer, "High Frequency Trading" (HFT) accelerated and compressed years of financial activity into just a few minutes, making what had been rare, commonplace.

For centuries, economic response times spread across planting seasons and ocean sailings. Stresses could grow slowly, and markets could respond lazily. The law of supply and demand had ample time to equilibrate within vague, elastic limits.[16] The industrial age sped things up. During the 1930s, new Keynesian controls responded, helping markets to equilibrate. Today, super-computational trading makes supply-and-demand far too slow to be effective equilibration.[17]

In 2000, statisticians at JP Morgan Chase led by Dr. David X. Li sought to justify risky investments. They adapted mathematical functions called "Gaussian copulas" or "copulations" to estimate the likelihood of market collapses.[18]

> The Gaussian copula soon became such a universally accepted part of the world's financial vocabulary that brokers started quoting prices … based on their correlations. "Correlation trading has spread through the psyche of the financial markets like a highly infectious thought virus," wrote … guru Janet Tavakoli[19]...

Gaussian curves show probabilities and correlations; "copula" refers to "coupling" those correlations. Financiers rejoiced that a foolproof mathematical formula guaranteed them success. As long as the tide of cash rolled in, they could ignore warnings.

> Nassim Nicholas Taleb, hedge fund manager and author of *The Black Swan*, is particularly harsh when it comes to the copula. "People got very excited about the Gaussian copula because of its mathematical elegance, but the thing never worked," he says. "Co-association between securities is not measurable using correlation," because past history can never prepare you for that one day when everything goes south. "Anything that relies on correlation is charlatanism." [20]

Enthusiastic reliance on Dr. Li's Newtonian equations was extremely important among the causes of the recent financial crash.[21]

Economists do admit that their science is not perfect. They cite a "human factor", by which they refer to the subtle behavior of consumers and businesspeople, but not to their own education, behavior, or psychology. Let us look at the human factor.

By "human factor", we refer to beliefs that cannot be sustained by evidence and logic. These include religious ideas that summon doubt and faith, and also superstitious beliefs that religions eschew as not "up to code". They also include accepting that emotions give life "meaning".

Most of us accept that cause-and-effect rules the everyday world. Everyone seeks some relief from reality in fantasy, and so may enjoy cartoons and movie special effects. Many people do "misunderestimate" cause and effect, however. They expect miracles, or turn to astrology for personal insight, even though the stars and planets can exert no possible cause to effect personality or destiny. Most educated people (even if reluctantly) understand that astrology is superstition.

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15 "The software models in question estimate the level of financial risk of a portfolio for a set period at a certain confidence level… Overreliance on financial software crafted by physics and math PhDs helped to precipitate the Wall Street collapse". After the Crash: How Software Models Doomed the Markets. *Scientific American*, Dec. 2008.

16 Elasticity describes a capacity to recover from stress, and return to a previous state. Beyond elastic capacity, return to form is not possible. Functional demand-supply equilibrium requires that no large perturbations like famine, war, or huge profit bubbles fatally stress "economic elasticity". Bubbling within the elastic range poses no problem. Unlike the case with solid materials, one cannot reliably predict when an economy will move from elastic resilience to brittle bubble bursting, but some bubble physics might help.

17 Note the market "glitch" of May 6, 2010 when the market fell 1000 Dow Jones points in a few minutes.

18 Mathematical Model and the Mortgage Mess, Dennis Overbye, NYT, March 9, 2009.

19 Recipe for Disaster, Felix Salmon; WIRED Magazine: 17.03, 12-03-09

20 Ibid.

21 "As Benoit Mandelbrot, the fractal pioneer who is a longtime critic of mainstream financial theory, wrote in *Scientific American* in 1999, established modeling techniques presume falsely that radically large market shifts are unlikely and that all price changes are statistically independent; today's fluctuations have nothing to do with tomorrow's—and one bank's portfolio is unrelated to the next's. Here is where reality and rocket science diverge. Try Googling "financial meltdown," "contagion" and "2008," a search that reveals just how wrongheaded these assumptions were." *Scientific American*, Dec. 2008, op. cit.

Planets in stable, repeating orbits *do* ignore cause and effect. This is not fantasy. Cause-and-effect implies that there may be something new and unpredictable. The planetary future is perfectly predictable. Otherwise, the sun would not rise on schedule. Knowing the Newtonian past allows perfect prediction of the future; moreover, one can perfectly recall the Newtonian past from the present. That is, one can perfectly trace Newtonian motion forwards and backwards in time. Newtonian time is thus symmetrical: circular and reversible. Equations that describe Newton's Laws offer certainty, not probability. These equations do not require or employ statistics. Even a previously unnoticed asteroid that crashes into a planet could have been predicted.

Thermodynamic science in the 19th Century radically changed perception in the physical sciences. *Thermodynamics makes it clear that there is no such natural, overall, universal symmetry or balance such as an "invisible hand" would imply*. The universe started as a Big Bang into chaos and irreversible time. Newton's Laws are special thermodynamic cases. They presume that all the energy in a system is already present, such that no fuel need ignite to start things. Furthermore, they presume that no energy is lost from a moving system, such that no new fuel will be necessary to continue it. *No quantifiable fuel factor is relevant to the law of supply-and-demand*.

While Newton's Laws discuss action-and-reaction, thermodynamics discusses cause-and-effect. Action and reaction are balanced, certain, and simultaneous, always adding to a zero-sum. Newtonian time is reversible, since either action or reaction may be a cause or and effect. A cause must precede an effect, implying "time asymmetry". *Asymmetrical time means imperfect prediction*. Causality therefore implies novelty and uncertainly, not perfect predictability.

Asymmetrical time means that any cause must have at least one future effect, but that any effect may have many past causes. No "retrospect-o-scope" can perfectly determine which possible cause was a root cause. We humans think of ourselves as causal; criminal law assumes that people are responsible for what they cause, and so cannot easily blame actions and consequences on external or prior conditions.

Perception has not yet changed in free-market economics. We infer that like astrology, belief in the "invisible hand" of the Free Market is a superstition. Free market economics expresses confidence in a cosmic order, in a serene balance that acts reliably and silently to bring events toward a harmonious equilibrium. The "genius of the market" was supposed to ameliorate the conditions that recently caused the world to crash. The "invisible hand" resembles a religious statue on the dashboard of an auto that occupants believe may protect them from the laws of physics.

Worse still, Newtonian economics encourages financial irresponsibility. Ignoring cause and effect rules out interest in the consequences of one's actions. Newtonian "balance" encourages believers in a free market to feel free to act as they please. Responsible roles dissolve; economics becomes a zero-sum game of which we non-financiers are spectators. The result is all about numbers, like batting averages, salaries, and shareholder value. [22]

War Story: Economic Efficiency Battles Maximum Profit

Economic theories address pricing*. None yet focuses on* profiting.[23]

"Economic efficiency" refers to maximal productive output from minimal resource input. The idea nevertheless puzzles. Economics extols "efficiency", and explains profit as "inefficiency". Yet, maximum profit signifies business success.

Businesses want maximal profit; buyers want minimal price. In "efficient" economics, unfettered competition and the law of supply-and-demand work toward a price equilibrium. Supply-and-demand cannot equilibrate at a perfect "break even" price,. "Efficient economics" assumes that a business makes a "normal profit". Otherwise, owners would better spend their time doing something else. Profits above "normal" are "economic profits".[24]

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22 Thanks to Howard Berens MD for these thoughts.

23 The last systematic theory may have been "Risk, Uncertainty, and Profit" by Frank H. Knight, published in 1921.

24 Albrecht, William P. (1983). *Economics*. Englewood Cliffs, New Jersey: Prentice-Hall

A gyroscope, used to stabilize sailing ships and space ships, is a spinning mechanism that demonstrates Newton's laws in action. A gyroscope is not perfectly efficient. It cannot spin forever because it loses energy to friction as heat. *No force of Newtonian motion can balance lost energy;* without fuel, any earthly mechanism will run down.

Smith's successors call normal profit irreducible "economic inefficiency". A real economy no more functions without producing profit than a gyroscope spins without producing friction. But, there is no Newtonian, economic model of replacement energy.

Newtonian logic leads toward the abyss. In an ideally efficient economy, supply and demand would be in such zero-sum balance that no one could become "better off" without making some one else "worse off".[25] Preposterous! Appalling! "No profit" is as sensible an economic ideal as a perpetual motion machine is an ideal automobile engine.

So-called financial "market efficiency" draws us closer to the abyss. "Market efficiency" does not refer to price equilibrium, but to all parties having the same information, which if so, would yield everyone only average profits. *Superior information makes a financial market inefficient, and rewards insider knowledge*. Supply-and-demand is hardly plausible in financial economics.

The idealization of a free market sets up a socio-psychodrama of moral antagonism. Because government interferes with the pell-mell pursuit of profits, free market mentality assigns to government the role of economic efficiency, and then fights against it. *Government regulation actually champions the free market*, protecting competition – which explains why corporations are so keen to influence the government. The most orthodox free marketeers insist that monopolies ought to be allowed to form, because they will fall apart of their own weight. Let ruthless, Darwinian economic nature take its course!

Free marketeers bristle at the implication of immorality that a need for government regulation implies, and (ignorantly) cite the holy image of the free market to justify themselves. Business corporations are legal persons without consciences. There can be no *scientific, moral,* or *historical* reason to believe in a free market, unless Jesus has identified profits as a promised land one is free to invade and conquer.

High Frequency Trading (HFT) is a product of free-market psychopathology in the age of supercomputation. The *Wall Street Journal* of August 1, 2009 reports:

> *Many high-frequency traders collect tiny gains… measured in pennies on short-term market gyrations. They [seek] temporary "inefficiencies" in the market and trade in ways that can make them money before the brief distortions go away*.

Market forces cannot restrain those who suck on "inefficiencies"; HFT makes war on the free market. These traders bite the invisible hand that feeds them. *High frequency profits represent insider trading in the age of the supercomputer*.

Opponents of economic regulation have reason to complain that government rules have "unintended effects". Relying even unconsciously on Newtonian physics allows the government to believe that the right mathematics might predict the economic sunrise.

Newtonian micro-management inspires resistance. Complex regulations encourage people to "game the system". Some strategies deliberately keep regulations vague not to prevent gaming, but to allow the government to play, "Gotcha". The result is a cops-and-robbers contest familiar to parents who seek excessive control over their adolescents.

Entropy Economics cannot preclude "gaming the system". Humans like games, starting with peek-a-boo. But, we do not need a dishonest, dysfunctional economic game.

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25 Sullivan, Arthur; Steven M. Sheffrin (2003). *Economics: Principles in action*. Upper Saddle River, New Jersey 07458: Pearson Prentice Hall. pp. 15. See also "Pareto Equilibrium."

Part II: *Fearful Asymmetry*

Newtonian science is overall, zero-sum; anything zero-sum overall is Newtonian.
Thermodynamic science is not zero-sum; anything overall not zero-sum increases entropy.

The Thermodynamic, Unbalanced Universe

> *"Thermodynamics provides a similar basic framework of statistical understanding for physics, engineering, and economics, as evolution provides for biology."*[26]

Life is not a perpetual motion machine. Life can run out of energy, and require new fuel. In the 19th Century, the growing importance of the steam engine inspired a new science of fuel and energy: thermodynamics, the *sine qua non* of the industrial age.

If economics is analogous to any physical science, it is thermodynamics. Thermoeconomic metaphors already apply. An economy may be "overheated"; goods and services are "consumed", as though by fire. Carefully to compare an economy to an engine so that we may understand a *thermo-economic engine*, we need to acquire a modicum of thermodynamic "literacy", and to become familiar with increasing entropy.

- Heat is thermal or "temperature" energy. Heat sets atoms into motion, to flow across a gradient from hotter to cooler, toward an equilibrium of average temperature.
- There is no spontaneous return from equilibrium back to separate, hot and cold states.
- Chemical bonds can overcome heat, and form complex molecules that store heat as "free energy". Fuels are molecules rich in free energy that a high temperature spark can ignite.
- Releasing free energy to flow toward temperature equilibrium destroys the structure that stored it. Otherwise, one could light the same match twice.
- *En route* to equilibrium, released energy can accomplish work like powering a car, but without perfect efficiency. Some energy is permanently lost to equilibrium.
- Heat flow ceases at equilibrium, the state of uniform temperature and maximum entropy.

> (Maximum) entropy may be defined as:
>
> the ultimate state [of] the degradation of the matter and energy of the universe**:** state of inert uniformity…**:** absence of form, pattern, hierarchy, or differentiation…[27]

- "Increasing entropy" describes losing stored heat energy and the structure that stored it.
- Without fuel to renew a temperature gradient, there is no more heat energy flow, and therefore no more power for work.
- Just about anything that can happen uses, and so *uses up* something as fuel.
- Since anything that happens uses fuel, entropy increases when virtually anything happens.
- Entropy therefore increases with time. Increasing entropy is the *"arrow of time"*.
- Universal thermodynamic equilibrium is no harmony of the spheres, but the end of time.

A singular thermodynamic event started the universe. A "Big Bang" launched existence randomly into future time, toward the inevitable, far-flung equilibrium called heat death. The galaxies, stars, and planets all came to their locations by chance, like popping corn gone rogue. Not much has changed since the Beginning. Heat still excites molecules. Whenever one lights a match, space expands a little to accommodate the flame.

Thereby hangs the tale. Increasing entropy is the sign of something, *the sign of <u>anything</u> happening*. *Virtually* <u>nothing</u> *can happen without increasing entropy*. Entropy is the famous "*waste*" that "*happens*". And, thereby *<u>really</u>* hangs the *tail*.

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26 Robert Wolf PhD, Emeritus Professor of Physics, Harvey Mudd College, Claremont, CA op. cit.

27 "entropy." *Webster's Third New International Dictionary, Unabridged*. Merriam-Webster, 2002. http://unabridged.merriam-webster.com (20 May 2010).

Increasing Entropy

In the mid 19th Century, Rudolf Clausius coined "entropy" (its symbol is "S") to refer to spent energy and lost molecular order. Thermoeconomics analogizes increasing entropy (*thermodynamic inefficiency*), and profit (*economic inefficiency*).

"Entropy" was well-coined; a "trope" is a "turn". In literature, a "trope" is a turn of phrase. In biology, a "phototropism" is a turn toward the light. In thermodynamics, entropy is "*transformation contents*", describing molecules as they turn, spin, and fly away. Entropy is forever "transformational", forever "between forms", and so in no form at all.[28]

Increasing entropy requires integral calculus to appreciate. We use arithmetic to illustrate simply why disorder increases as heat releases. [Appendix A presents a fuller treatment.]

Room A and room B are adjacent and equivalent. A is hotter, at 60°; B is cooler at 20°; their distinction is a simple state of order. When a door opens, heat energy measured in joules disperses between A and B. Room temperatures equilibrate at 40°. No joules of energy are lost or gained overall. No degrees of temperature are lost; they meet in the middle, at equilibrium. So far, everything is zero-sum (or, "Newtonian").

Recall that as temperatures rise, molecules bounce around more energetically. As air in rooms A,B heads toward equilibrium, the molecules in the cooler room speed up as they warm. The molecules in the warmer room slow down as they cool. *Here's the rub*.

> Flowing toward A,B equilibrium, cooler molecules speed up as they warm *more than* warmer molecules slow down as they cool. Warmer molecules move more energetically and so are more randomly distributed than cooler molecules; randomness measured as entropy increases overall. *This is no zero-sum balance; order is not conserved*.

Here is another way at look at it. At average temperature equilibrium, molecules from A,B have twice the space in which to roam. It is now equally probable that *any molecule* can be *anywhere* in the two rooms, as opposed to being within one or the other. At equilibrium therefore, the "orderly" distinction of temperatures between the rooms is lost. This is a *net increase in disorder*, and a net loss of location information.[29] *Increasing entropy represents the greater space into which the molecules disperse*.

Energy may be dispersed, but not created or destroyed; energy is conserved. Entropy increases, however. "Joules" therefore cannot denote both energy *and* entropy.[30] Entropy increases over a *range of temperatures* in units of *joules-per-degree*.[31].

Our room A,B example stands for any thermal gradient. Molecules everywhere tend to fly from each other into expanding space and future time, toward equilibrium and oblivion. The universal finality of thermodynamic equilibrium identifies the Law of Entropy as the *law of laws*. Heat disperses, space expands, entropy increases, information is lost, and time travels.

The concept of entropy travels well into the social sciences; here is how. Mix hot and cold water in a bathtub. At equilibrium, those water molecules are maximally, randomly dispersed. *Maximum entropy describes maximal microscopic chaos*, the *maximal uncertainty of any individual*

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28 Entropy is "transformation", which is the opposite of "information". *Unlike matter and energy, information can be created and destroyed*. Destroying information creates transformation products, such as ashes. Perhaps because entropy (unlike matter and energy) can be created, communication scientists define entropy ***as*** information. They refer however to a capacity to carry bits of information along a telephone cable. They have no interest in (or a unique word for) the nature or content of a message. **Note that unlike information, entropy can be created, but not destroyed**. In another context, *information* and *transformation* are complementary concepts, as "redundancy" and "individuality". There is no meaning in a message without symbolic order; there is no order without redundancy. Messages are not very worthwhile unless individual; entropy represents a capacity to create individual messages, at the risk of chaos. In information science, redundancy describes wasted cable carrying capacity.

29 *Unlike matter and energy, information can be created and destroyed*.

30 *Unlike information, matter and energy cannot be created or destroyed*. See also Appendix A

31 Thermodynamics mavens knowing integral calculus will recognize the simplification we use to approximate this point.

particle's location at any time.[32] At the same time, all those randomly dispersed molecules taken together have a precise average temperature. So, *maximum entropy identifies maximum macroscopic uniformity or order* at the same time as it identifies *maximum microscopic chaos*.

Entropy applies to populations of humans as well as of molecules. Average earnings describe group behavior. What any individual earns or buys at any time is not predictable. Maximal entropy describes both the *maximum social uniformity* that conservatives fear, and the *maximum microscopic social freedom* to think and behave as one pleases that pleases liberals.

Reconciling Symmetry and Asymmetry

Scientists at first wondered about incompatible, Newtonian and thermodynamic theories. In the later 19th Century, scientists reconciled Newton's reversible Third Law and the irreversible Second Law of Thermodynamics thus: Molecules are objects, like little billiard balls, so Newton's reversible laws must apply; their motion must be reversible. In the unlikely event that all molecules reversed in the same direction at once, water might flow uphill! According to Boltzmann's Statistical Interpretation of Thermodynamics, it is possible that such an event might happen once every 10 eons or so, give or take.[33]

Recall that molecular formations holding heat energy are lost when heat releases. Burned particles at temperature equilibrium will not again be in formation. As a result, using heat increases overall molecular disorder irreversibly, losing stored information.[34] Newtonian law is *deterministic*, but thermodynamics is statistical or *probabilistic*.

Because whatever *uses* energy *uses up* energy and loses molecular information, every thermodynamic event is *individual* rather than repeatable. Because they are not repeatable, individual events are not perfectly predictable. Think of the bell-shaped curve! It is surely counter-intuitive, but *cause-and-effect makes things not perfectly predictable*. Newtonian mechanics + thermodynamics = thermodynamic, statistical mechanics.[35]

Economists use statistics and the "bell-shaped curve" every day. They seem not to know that there are no Newtonian statistics.

Well, there actually are, sort of. Dice-throwing gamblers, contemporaries of Newton invented statistics to calculate their odds. There is a term among statisticians, "casino statistics". Many in the finance community do seem more like gamblers than like scientists. Economists may easily have accepted an aleatory (dice-throwing) world-view that permits them to feel safe to ignore outliers (unusual events). After all, there are only so many ways dice can land. Casino statistics ignores that throwing dice causes them to fly.

Speaking as the "last Newtonian", Albert Einstein famously complained, "God does not play dice with the universe". Einstein sought a unified, god's eye view. Molecular randomness seems intrinsic however, such that sensed reality must be constructed of individual probabilities. In the last analysis, reality is only a high probability.

Two Opposed Concepts of Equilibrium: Newtonian and Thermodynamic

"Equilibrium" in Newtonian and thermodynamic systems differ greatly. Newtonian equilibrium is a state of balance and order. The earth orbits the sun at Newtonian equilibrium, because centrifugal forces balance gravitational forces. In Newtonian economics, demand and supply balance, and equilibrium means stable production, stable prices, and prosperity.

Thermodynamic equilibrium is no ideal. It occurs as temperatures balance. Without a

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32 "Thermodynamics, Evolution, and Behavior" by Rod Swenson, Center for Ecological Study of Perception and Action, Univ. of Conn.; from Encyclopedia of Comparative Psychology, Greenberg and Haraway (eds.) New York: Garland Publishers 1997

33 Readers of Douglas Adam's *Hitchhikers Guide to the Galaxy* will have come across this idea as the "infinite improbability drive".

34 Molecular structure is stable "in formation". The word-play is deliberate.

35 There is no "statistical mechanics" without thermodynamics. Interested readers may want to learn about "Maxwell's demon", and evidence that Newtonian observation cannot reveal statistical mechanics.

temperature gradient, heat flow ceases. Without heat flow, there can be no thermal energy to accomplish work. In thermodynamics, equilibrium is heat death.

Adam Smith's free market is a Newtonian fantasy, an ideally balancing cycle of supply and demand. Economics cannot possibly fully describe the real world that way.

Not Applying Entropy Economics: a Cautionary Anecdote

Newtonian perception of the universe is balanced and symmetrical. Thermodynamic perception of the universe is unbalanced and asymmetrical.

Here is a cautionary tale of symmetrical versus asymmetrical, business thinking. American auto companies traditionally relied on *symmetrical*, demand-supply factors like economies of scale to keep manufacturing costs low and to maintain market dominance. None addressed product quality and reliability during manufacturing. All expected a buyer to function as a quality control feedback stage, asking for repairs (under warranty) upon discovery of flaws. R*epairs were just another profit center (for the dealer) within a cloud of financial data*. In effect, these companies ignored that what happens before (including manufacturing) and after a point of sale are distinct and asymmetrical; manufacturers ignored their effects on customers.

In contrast, Japanese auto companies used an *asymmetrical* model. They did not require the customer to perform the companies' quality control duties and respond as though they were an unpaid part of a feedback loop. In the 1970s, Japanese companies focused on error reduction in manufacture. Superior quality control delivered defect-free products to happy customers. Reducing "product entropy" – product defects and manufacturing waste – both raised profitability and won market share. Japanese auto manufacturers recycled profits to make *kaizen* and *kanban* approaches ("continuous improvement" and "just-in-time scheduling") ubiquitous. Both improve quality while reducing waste.

This completes the "basic science" that we need in our "toolbox" as we proceed.

Part III: *From Thermodynamics to Thermoeconomics*

Inventing a Hybrid Economic Temperature

Many think of profits as "investment fuel". Economists know profits as "economic inefficiency". As waste products of economic combustion, profits represent "thermo-economic inefficiency".

We begin to develop thermo-economics as we compare Buyer-to-Seller transactions to the heat diffusion example, from room A to B (Part II). Analogy requires that economic variables correspond strictly to thermodynamic variables, and that identical mathematical functions operate on each. (We shall find that they do not quite work.)

The economic analogy to *joules* of heat is *price,* in units of currency. In a diffusion model, we posit a Buyer who purchases a horse for $200. Dollars flow from Buyer to Seller across a "desire" gradient (Fig. A and below), in analogy to joules of heat flowing from room A to B.[36] The purchase transforms "analog" horse into "digital" cash.[37] The received sale price "heats up" the Seller and releases the horse, which moves toward the Buyer.

If it cost $150 to bring a horse to market, $150 recovers those costs. The $50, non zero-sum remainder is *profit*, which alerts us to wonder about increasing entropy.[38]

Beings were not relevant in the physical room A,B example, but are in thermoeconomic transactions because they imply a *before-life* of *information exchange* -- even if just to note a price in an ad. *Information exchange does not imply energy exchange*. We posit a transparent wall (like a store-front) between Buyer and Seller. Economic "joules" flow only if a door opens, and Buyer-Seller economic "temperatures" equilibrate at a sale price. (See Appendix B.)

Relative distance from absolute zero is what matters, so **any temperature scale rising from absolute zero can be valid in thermodynamics**, including one we imagine, estimate, and apply to thermoeconomics. In Figure A, we estimate Buyer "economic temperatures" relative to zero.

Psycho-economic Temperature (T_E) describes subjective Buyer "demand" or "desire".[39] Just as 100°C rise from freezing to boiling water, we posit that "ten degrees Greenspan" (10°G) span economic liquidity. (Alan Greenspan, former Federal Reserve Bank Chairman, coined "Irrational Exuberance" during the Dotcom era.) T_E values range from Depression near absolute zero, to white-hot Mania at 10°G.[40]

Intentionality or "rational choice" is central. Necessity implies less choice. Modicum of Interest needs a hard sell; Depression means staying in bed.

Above Intentionality, rational judgment melts into enthusiasm for fads and fashions. Further above, Irrational Exuberance yields to Mania. Gambling on real estate and assuming wild credit card debt qualify here.

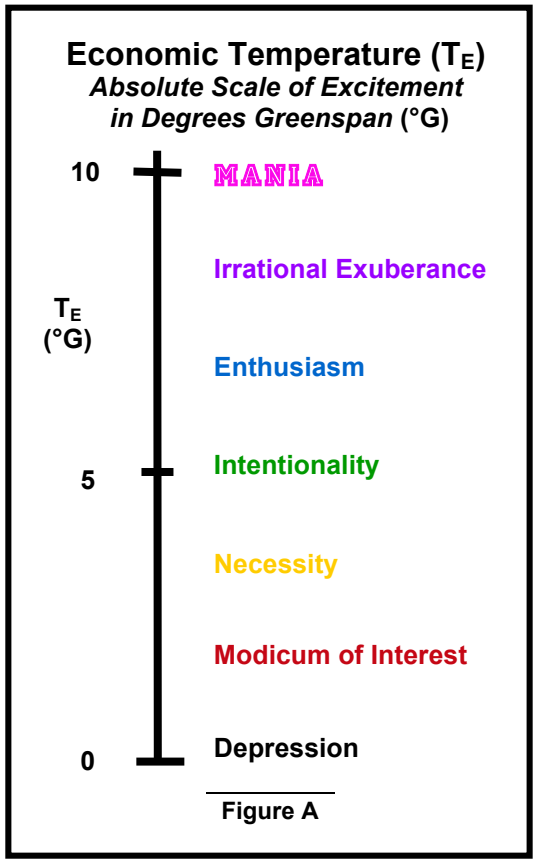

Figure A

[36] A Buyer of a horse brings "hot cash", and is literally "hot to trot", eager to "consume".
[37] Transforming an object into cash is the original "analog to digital" conversion.
[38] This correspondence will appear more vividly for some in Appendix B, which presents relevant equations.
[39] Heat excites molecules, increasing pressure against a container. Desire heats up people, and puts pressure on behavior.
[40] See also: Study: Your Brain Thinks Money Is A Drug by David Kestenbaum. Nat'l Public Radio August 7, 2009

In Part II, we noted that joules cannot apply both to energy and to entropy. One calculates changes in entropy across temperatures not in joules, but in *"joules-per-degree"*. Similarly, dollars cannot refer both to price and to profit-as-entropy. In *Appendix A*, we introduce "Transaction Profit" to refer specifically to profit as "financial entropy". In analogy to "joules-per-degree", we write financial entropy as "*dollars-per-degree Greenspan*".

"Work, Work, Work, Work" [41]

In a diffusion example, joules of energy travel from A to B. In Part II, we noted that heat diffusion cannot accomplish work; heat diffusing between rooms cannot power a car. It requires an engine to do so. We would therefore also expect that "price diffusion" from Buyer to Seller cannot account for thermoeconomic work, whatever that might be. To account for economic work, we shall need a model of a *thermo-economic engine.* [42]

But first: what is work? In physics, work is an amount of *force* transferred across a *distance*. Weight is a force, and height is a distance. Lifting the weight of a bucket of water through a height is work. Like transfers of energy, work is measured in joules. Joules therefore measure both start-to-finish work cycles, and A to B heat transfers.

A cycle of work expends joules of energy, but joules are neither lost or created. Joules therefore do not describe increasing entropy, and one calculates joules of work ignoring the use of fuel. Ignoring fuel, a work cycle is as zero-sum as a planet in orbit.

Engines perform work in cycles. A piston in an engine passes through a work cycle, and returns to its origin to begin another work cycle. What makes an engine work cycle not Newtonian is the need that new fuel ignites to begin another cycle.

In a thermoeconomic engine model, a cycle of thermoeconomic work restores a production system to its previous state, ready for the next production cycle.

Recovering costs in the diffusion-economic example releases the horse to pass "upstream" from Seller to Buyer. *Nothing diffuses from B to A in the heat example*. The diffusion, economic model is thus illustrative, but not fully analogous. In *Appendix B*, we further discuss thermoeconomic work in analogy to a "Carnot Engine".

Economic Work Recycles Value, and Sequesters Profit

If profit functions as entropy, and if entropy is waste, can profit cause environmental pollution? Why not? After all, every molecule of industrial pollution is profit-driven.

Businesspeople assume that profit is their just desert for the work of bringing a product to market. Many consider profit the valuable, divine fuel of future enterprise. We however perceive an analogy of profit and entropy, which is waste. "Is a puzzlement!" [43]

We know that chemical bonds form molecules that trap heat as free energy. *We posit a thermoeconomic analog: "production-cost-energy"*. Industry organizes resources into products and services. Like complex molecules storing energy, products and services store the work-energy that brought them to market. Both work and energy may be measured in joules; the thermoeconomic analogy to joules is cost, in units of currency.

Heat energy stored in fuel is a capacity to perform work; the same applies to production-cost-energy. Recovering the dollar cost-to-market completes an economic work cycle, and prepares economic conditions for another production cycle. The aptly named "consumer" ignites the release-recovery of production-cost-energy at a point-of-sale.

- Recoverable production-cost-energy is thermoeconomic "value".

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41 Spoken as his head poked through a closed curtain by Governor WJ LePetomane (Mel Brooks) in *Blazing Saddles*.
42 See Appendix B
43 Oscar Hammerstein, lyricist of *The King and I*

- *The work of a thermo-economic engine recovers value in a production cycle*.

To recover value just "breaks even", however. Enter profit. To profit, something is sold at a price inflated, even if only slightly beyond cost. We earlier discussed "normal profit" as the minimum that owners require to stay in business. Normal economists include this "opportunity cost" as a "given" in break-even supply-demand calculations. Nevertheless. any proceeds beyond breaking even must function mathematically as increasing entropy, even "normal profits". Normal profit is a "fudge factor" that keeps the free market plausible to those who wish it so.

A barter system exchanges objects of intrinsic utility to each party. Currency transforms intrinsic utility into exchange value. Perhaps this means that currency is entropy in your wallet. That cannot be. Currency that recovers costs has *intrinsic utility* for the seller; a seller functions as a consumer to his/her suppliers. Profits, not price, represent increasing entropy. Like joules of energy *vis a vis* entropy, currency by itself does not distinguish value from profit. (Appendix B has more about "transaction profit".)

If there were a fixed amount of currency, there would still be no advance from a break-even, barter economy. Profit creates circulating currency. Circulating, accumulating profit inflates money supply; each profitable transaction expands economic space. (Every lit match expands the universe a little.) Profit accumulation ensures that there is more money in a system than is in use at any given moment; banks store and distribute excess cash. So far, profit seems necessary and wonderful, if not miraculous.

Alas. A financial economy must make profits, which inflate price. *There is no natural model of necessary, net increase except increasing entropy, which is waste*. There is no production either in industry or in biology without waste. Finance is no different.

This is no joke. A biological body is a well regulated, food-burning furnace. Bodily waste carries away the increasing entropy it necessarily produces. (In Europe, a privy or bathroom is sometimes called "the necessary".) Correspondence between profit and biological waste is not far fetched. Compare a business taking a bite out of an economy and generating profits, to a baby feeding and then "doing its business".

One concludes that profits signify a healthy economy much as a loaded diaper signifies a healthy baby. *Both signify healthy metabolism*.[44] A toddler grows up as s/he learns not to worship what s/he produces. The same is true of financiers and their profits.

Identifying profit as increasing entropy means that profit cannot be the fuel or the goal of value recovery. Transforming profits directly into value would be like spinning straw into gold – possible only in the imagination. Profit (like happiness)[45] is a by-product. Making profits was never the *goal* of economic activity, anyway. *Even free market fundamentalists agree that the goal of an economy is the well-being of civilization*.

Guess what? We have created an *imaginary* friend (like a golem) with the "magical" power (to appear) to turn profits into value! That creation is the business corporation, a fictitious, "legal person" with real rights and responsibilities (but with no conscience). Business corporations serve as profit treatment centers.

Natural farmers return manure to the ground to mix with sunlight and earth to produce fertilizer for new crops. Farmers can recycle manure, because it retains useful energy and other components. Industry returns profit to the "ground" to mix with new product and service value.

One cannot recycle entropy; there is nothing in it to recycle. To believe we can recycle profit is wishfully to imagine that profit retains some energy.[46] We must conclude that we create or produce commercial value to sequester profits, and not to derive or rescue value from them.

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44 Thieves broke into a gas station, and stole all the bathroom fixtures. The police were baffled. "We have nothing to go on", they said. (NPR's *Car Talk*: Tom and Ray Magliozzi, July 3, 2010)

45 Attributed to Eleanor Roosevelt

46 It remains to understand whether or not profit retains any useful internal energy (exergy).

Active industry reduces local entropy because it uses free energy, which traces back to the sun. One cannot make any new product without overall increasing physical and financial entropy, however. New production of course must also sell at a profit. Creating value may sequester profits, but cannot reverse entropy *overall*. The great question is: can civilization keep entropy production in line with free energy imported from the sun?

Financial profit bubbles suck in real value as they grow. As economic, buying temperatures lift toward "Irrational Exuberance," profit bubble growth outpaces the capacity of new value to manage profit sequestration. When bubbles at last break wind, they release both paper-vapor profits and unused, real value in gales of increasing entropy.

Nothing inherently keeps expanding finance from thermofinancial equilibrium, such as we approached in 2008, when hot-air balloons of real estate profits just floated away. No one knew where the money went, or could fund economic work. Few outside the banking system understood that only a great infusion of value borrowed at great risk from the future could fuel recovery.

Despite all this, many financiers still prefer to generate profits from profits rather than to invest in value recycling. Labor and energy do not mix with and so cannot sequester "unvalued" profits. An external mechanism like the Federal Reserve may help, but competitive, industrial profitability with minimal finance is the only rational way to regulate money supply.[47]

This is revolution. *We need a 180-degree revolution in our thinking*. Profit does not drive value creation, except to capture and sequester profit. To sequester huge amounts of profit and so regulate economic growth is the true function of business corporations. Any other view of profits seems infantile and unsanitary.

The Buyer-Seller Relation

Noting that a consumer "ignites" the fuel of thermo-economic work recognizes that Demand drives economics as cause drives effect. Consumer ignition identifies the "rational actor" whose motivation economists presume is survival. Some scientists use "behavioral economics" or "neuro-economics" to study actors in statistical groups, rather than as individual beings. We consider "psycho-economics" to operate within an individual – whether or not the actor is rational.

Because any temperature scale rising from absolute zero works for thermodynamics, we postulated a "Buyer temperature". We estimated a desire to buy as a subjective pressure or tension that purchasing relieves. In heat diffusion, heat diffuses from warmer to cooler. In economic diffusion, desire-tension passes as cash from Buyer to Seller. We suspect that a "pleasure principle" [48] associates purchasing with Buyer tension reduction, and pleasure with survival.

Pleasure is less a specific feeling[49] than relief from tension, pain, sorrow, fear, anxiety, or desire[50] -- "unpleasures" all. Eating relieves hunger; company reduces loneliness; romance fulfills desire; shopping relieves anomie.[51] Insofar as anxiety is a threat to "fly apart", we consider that anxiety represents increasing entropy, and that anxiety reduction restores mental order.

We associate "worth" with buying, and "value" with selling.

Worth exists in a Buyer's "mind of profit"[52] as an expectation sufficient to make purchasing pleasurable, even at a non-bargain, profitable price. A mind of profit may ignore other considerations like personal finance, workers' rights, and environmental impact.

Two elements define worth, and so affect buying desire and buying pleasure. One is objective utility; a Buyer might need a horse to travel and to plow. A horse might also have a sub-

[47] In a well regulated, thermofinancial system, criminals and cults will find laundering money difficult – but that is another story.
[48] Not an idea original with us.
[49] We do not refer here to states of chemically heightened pleasure or euphoric mood.
[50] Anyone who has known unrequited love has learned that desire without release is suffering. Desire is a passion; passion is from the Greek for "to suffer". The Easter story of crucifixion is "The Passion" of Jesus.
[51] "When the going gets tough, the tough go shopping".
[52] Adapted from Wallace Stevens' poem, *The Snow Man*: "One must have a mind of winter…"

jective, social utility. A Buyer might want a horse to impress a woman he wants to marry. *Worth is thus equal to objective plus subjective utility*. Purchasing the horse relieves the felt need of it, so a Buyer experiences a *horse's worth* of pleasure.

Two kinds of utility imply two kinds of pleasure. Drinking a glass of water to slake thirst brings objective, physical pleasure. Drinking identical-tasting, branded, bottled water in a restaurant and feeling "hip" or "cool" affords a subjective, *social status* pleasure. Advertising subtly blends these pleasures into a cocktail.

We know that *reducing* physical tension affords pleasure, but there is also pleasure in perceiving an *elevation* of one's social status. Perhaps *elevated* social status *reduces* social anxiety. A good name for social-status pleasure is *pride*.[53],[54]

There is obviously more to profit than pricing for objective utility. Sellers like Apple excel at inciting "minds of profit" so that a "cool", social status factor may drive sales success beyond logic. One might expect the utility of warm coats in a cold climate greatly to matter. Not many coats may be sold, however, without attention to coats as status-conscious, "fashion statements".

Ponzi-schemer Bernard Madoff succeeded because he aroused great social-status anxiety among his prospects. He convinced them that they would be favored people receiving "insider treatment". Madoff demonstrated what advertisers know, that the subjective, "mind of profit" is easily blinded by status flattery to objective reality.

A Buyer to Seller "economic diffusion" model assumes that Seller and Buyer temperature meet at a sale price, and that the tension that purchasing relieves of the Buyer diffuses on to the Seller. Buyer "chills" by a "horse's worth" of pleasure, and passes tension to Seller, who "heats up" enough to release the horse to pass on to the Buyer.

Seller has received a horse+ of tension, which is recovered cost to market *plus profit* (increasing entropy). The Seller has become more stressed (horse-plus) than the Buyer has calmed down (minus-horse). The Seller then does his-her business. The pleasure principle is at work; when the Seller relieves him/herself of tension, the result is more net pleasure than there was in Buyer tension-relief.

We inferred a Buyer before-life of information exchange. Now, we may wonder about a Seller afterlife. Unlike a closed heat-diffusion system, proceeds from a sale enter the larger economy, and circulate to recover costs, and to invest.

If a Buyer has a *mind of profit*, then a Seller has a stronger *profit motive*: selling satisfies relatively more than buying can gratify. Advertising is necessary to encourage buying, but not selling. Most folks will sell anything for the right price. *Psychology enters economics as* Buyer *demand, but it exits as the* Seller supply-side *profit motive*.

One expects that greed is intrinsic to the sell-supply side of economics, just as bargain hunting is intrinsic to the buy-demand side. We intend science here, not moral judgment.

When the idea of economics as demand-driven ran up against supply-side economics in the 1980s, no one recognized the underlying error of Newtonian economics as we have identified it: if economic drives are reversible and symmetrical, then it does not matter whether supply or demand is the driver. In the asymmetric, thermoeconomic model, desire for a horse must come before the cart that carries off the cash.

The pleasure principle warns us that the drive to sell may dissociate from any value to an economy. Free marketeers pretend that market forces can limit such behavior, but the free market unprotected by the government regulation of competition and the taxation of super-computed profiteering in fact enables and rewards such behavior.

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53 We avoid the bogus vulgarism, "self-esteem".

54 Perhaps there is an emotional, pride-shame principle perpendicular to a physical, pleasure-pain principle. One feels pride getting a promotion, having a child, winning a prize, or paying for dinner. One can feel embarrassment if one's clothing is unsuited for an occasion. One can feel shame at the public revelation of betraying one's friends.

The Second Law and the Pleasure Principle bear a resemblance.[55] The profit motive, the pleasure principle, and the thrust of the Second Law toward heat death seem inseparable. We need not be surprised therefore if the pleasure-driven pursuit of profit resembles a death instinct.

Civilization produces entropy beyond what is ecologically sustainable. Why? The next Section offers a hypothesis.

The Law of Maximum Entropy Production

Life seems to evolve toward greater order, against the entropy gradient and probability. Some argue that this implies a creator god. Rod Swenson astonishes conventional perception. Life does not evolve against the entropy gradient. [56]

> *The Second Law says that entropy [maximizes,] …but it does not ask or answer the question of which …available path a system will take [toward] this end. The answer…is that the system will select the path [of least resistance} … {that] maximizes entropy at the fastest rate given the constraints.*
>
> *…Consider the case of a warm mountain cabin sitting in cold, snow-covered woods. The difference in temperature between the cabin and the woods constitutes a potential [or gradient]. The cabin-woods system will consequently produce flows of energy as heat from the cabin to the woods*...
>
> *Suppose the house is tight and heat is flowing to the outside primarily by conduction through the walls. Imagine now opening a window or a door, which amounts to removing a constraint on the rate of dissipation. We know and can confirm by experiment that whenever a constraint is removed and a new path or drain is provided… the system will seize the opportunity [and the cabin will cool more rapidly than before]. … . The point is that … the system will automatically select … from among available [paths] those [that] get the system to the final state… at the fastest rate given the constraints.* **This is the essence of the principle of maximum entropy production.**[57]
>
> *Given what we have discussed… the reader may have already leaped to the correct conclusion. If the world selects those dynamics that minimize … [gradients] at the fastest [possible] rate, … then the world will select order when… it [can].* The world is in the order production business because ordered flow produces entropy faster than disordered flow, *and this means the world can be expected to produce as much order as it can [so that it may subsequently create as much more disorder as it can.]* [58]

The Law of Maximum Entropy Production favors producing order because it is the most efficient way to create disorder. Sounds like a summary of capitalist economics!

If life evolved to increase entropy efficiently, then civilization evolved further to amplify entropy production. The love of profit thus seems no drive toward prosperity, but toward industrial pollution and oblivion.

Conclusions and Inferences: Saving Capitalism

Putting some pieces together, we recall that waste happens and entropy happens. If profit is entropy, then in economics, profit happens. If currency in thermoeconomics is analogous to joules of energy, then we know at last why cash can burn a hole in one's pocket. We may conclude: Spending Happens.

We have a scientific problem. An economy is no celestial mechanism, but a belching ma-

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55 See also *Animal Sprits*: How … Psychology Drives the Economy…" By G.A. Akerlof and R.J. Shiller, Princeton Univ. Press. See *Beyond the Pleasure Principle* by Sigmund Freud, as well

56 "Thermodynamics, Evolution and Behavior", Rod Swenson, Encyclopedia Comparative Psychology, 1997

57 Emphasis ours

58 Without referring to their predecessor Swenson, other authors opine: "Ironically or paradoxically...the complex system more effectively accomplishes … entropy production than [does a simpler, less organized system]. *Into the Cool: Energy Flow, Thermodynamics, and Life*; Eric Schneider and Dorian Sagan; Univ. Chicago Press, 2005.

chine. Free marketeers use quasi-religious, "invisible hand" rhetoric to intimidate logic. Their willful ignorance of physical science serves only the interests of reckless financiers. *We argue to protect the role of free capitalism in a political democracy.*

Some argue that simple greed perturbed the financial system and precipitated the recent crisis. Even if there were no greed, that profits unavoidably inflate prices above cost-to-market means that thermofinancial regulation is intrinsically, scientifically necessary. The issue is neither moral nor legal, but scientific. Unvalued profits accelerate the flight to thermofinancial equilibrium.

Keynes knew that deficit spending helps recovery. During recession, when no inflation erodes value, deficit spending generates value-based purchasing power. Building bridges and roads creates new product cost value, and gives workers cash. Public funding of necessities like infrastructure and health care also frees up consumer money. Not earning huge profits keeps entropy generation low. Still, one wonders if there is a fine line between overspending and inflation, and underspending and economic collapse.

When pre-industrial response times spread over planting seasons and ocean sailings, an economy could respond gradually. The industrial age sped things up; Keynesian controls during the 1930s adapted. Today, super-computational, high-frequency trading is a slight of hand that renders supply-and-demand unable to preserve market efficiency.

We call for the discipline to restrain economic entropy production to within what we can recycle. The decline in tobacco smoking among Americans is a good example of how well education can work to change consumer habits.[59]

The contest between cap-and-trade and carbon taxation regimes to control pollution reduces to a Newtonian versus Thermodynamic debate. Cap-and-trade ignores the cause of pollution, and uses finance to trade in toxic effects – giving financiers huge profits. Carbon taxation, the thermodynamic solution, addresses the carbon problem before carbon enters the atmosphere.

Whatever happens, there is no need for socialist, central economic planning. Central planning stifles innovation; proper regulation encourages it and rewards it.

To paraphrase an old theater song, "Life is a baseball game, Old Sport". You cannot plan a baseball game, but you can umpire it. A confirmed set of rules makes a game worth playing.[60] The more violent is a sport, the more it needs firm regulation – like football, hockey, or boxing compared to bowling. *Economics is a blood sport*.

It remains to define how to measure recycled product-cost-value in terms of capital, labor, and environmental impact. Many nations use value added taxation or VAT. We would use a non-value added tax or NVAT to address the lack of financial profit sequestration. Many financial products will score a high NVA and be commensurately taxable.

Entropy economics argues for financial regulations that keep an economy away from "tipping points". Working with the profit-value connection in financial products, we can reduce bubble-formation dynamics, and stave off dangerous financial fluctuations. We expect proper regulation to restore the former 100-year interval between financial tsunamis by slowing the rate of increasing entropy. If the financial sector is sufficiently well regulated, capitalism may yet take care of itself, and of all of us.

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59 Illegal drug trade injects non-valued profits into the international finance system. Honest drug education can effectively reduce demand for drugs.

60 Thanks to Richard Kullberg

Appendix A: From Thermodynamics to Thermoeconomics, again

Thermodynamic Event: Consider an isolated system of two identical, adjoining rooms, A and B; see Figure 1. The air in room A is hotter, at 60°, and cooler in B at 20°. This *distinction* of rooms and of temperatures represents a state of '*order*' or *'low entropy'*.

Hotter molecules disperse more forcibly than cooler.[61] As a door opens, the 60°/20° gradient (Fig. 1a) drives heat 'Q' *measured in joules* across it. Temperatures fall in A, rise in B, and equilibrate at 40°; no degrees are "lost". The change ('delta' or 'd') in heat 'Q' is 150 joules, noted as dQ, that pass from warmer to cooler (Fig. 1b). No joules are lost; *as with temperature, heat changes are zero-sum*. At equilibrium, heat dispersion is maximal, and by definition so is entropy.

With both rooms at 40°, the A-B distinction is lost; air molecules have twice the space in which to disperse. This is a net *increase in disorder;* it is equally probable that *any molecule* is *anywhere* in the two rooms. Maximum entropy, equilibrium, and "tending toward average probability" or "regression toward the mean" are allied concepts.

To calculate entropy:

(1) $\Delta S = dQ/T$

Divide joules passing from A to B by the *average* temperature as each room equilibrates.[62] In A, the average as it cooled was 50°; the average was 30° in B as it warmed. Compare 150/-50=-3 joules/degree and 150/+30=+5 joules/degree. Entropy falls in the warmer room, as it cools (-3) less than entropy rises in the cooler room, as it warms (+5). *Entropy increases overall more than it decreases*.

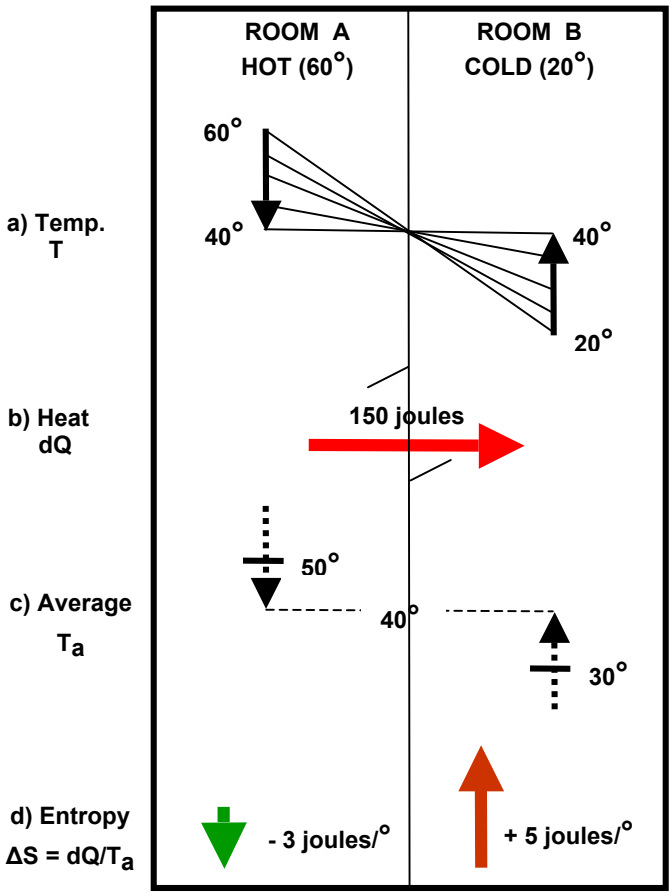

Figure 1

Economic Event: We compare funds and goods passing between a Buyer and a Seller to heat diffusing between A and B. Strict analogy requires that each economic variable correspond to a thermodynamic variable, and that identical mathematical functions operate on each. A difference: beings may observe physical systems, but enter economic transactions. Some thermoeconomic constructs may therefore be *"psycho-economic"*.

Any temperature scale rising from absolute zero is valid for thermodynamics, and so for thermoeconomics as well. We can only estimate a Buyer's economic temperature, but we can use that number objectively. What matters is relative distance from absolute zero, setting up a flow toward equilibrium of "warmer" from above and of "cooler" from below.

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[61] NB: Temperature measures molecular excitement, not heat. A tub of cool water holds more joules of heat than does a lit match.

[62] This is a useful approximation. Increasing entropy is actually calculated by integrating the heat transferred over all temperatures.

Our psycho-*economic Temperature* scale (T_E), marks the pressure called "demand" or "desire" that drives economics[63] (Fig. 2 below). In analogy to the 100° Celsius that range from freezing to boiling water, we posit that "ten degrees Greenspan" or 10°G span economic liquidity. (We name our T_E scale for the former Federal Reserve Bank Chairman, Alan Greenspan; he coined "Irrational Exuberance" during the Dotcom era.) A spectrum of approximate values range from dark Depression approaching economic, absolute zero, to white-hot Mania at 10°G.[64]

In the center is Intentionality, denoting the sober equilibrium of "rational choice". Necessity below implies less choice. Modicum of Interest further below may describe aimless window-shopping or web surfing. Depression means staying in bed.

Above Intentionality, judgment fades into fads that are "all the rage". Enthusiasm implies emotional interest and social status gain. Further above is Irrational Exuberance, yielding to Mania. Examples of the latter are gambling on real estate bubbles, and accumulating credit card debt to fund garish purchases.

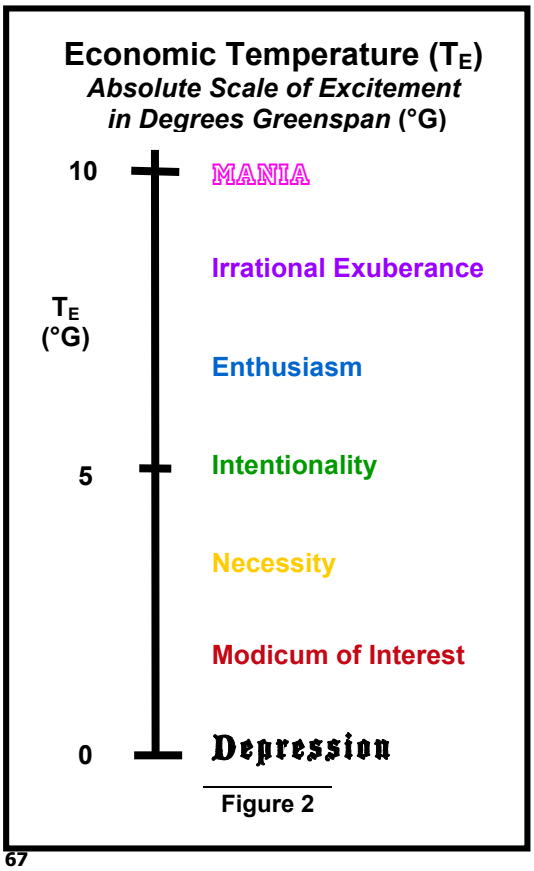

Figure 2

We replace rooms A,B with Buyers and Sellers.

We measured heat flow in joules. *The economic analogy is price, in units of currency*.[65] Paying $200 for a horse, dollars of currency flow from Buyer to Seller across the desire gradient; desire has transformed "analog" horse into "digital" cash.[66] Time passes; money and goods change hands. Dollars "heat up" the Seller, and release the horse, which passes toward the Buyer.

If the seller expended $150 to bring a horse to market, $150 cash works to recover costs to market. This is no balanced, action-and-reaction, for profit accrues in a successful transaction. The $50 profit margin makes the transaction non-Newtonian. Since the only physical quantity in nature that must increase with time is entropy, we surmise that the $50 *profit alerts us to increasing entropy*.[67]

We calculated physical entropy as "joules/average degree". To equate profit with entropy, we use an analogous quotient: "dollars/average degree Greenspan" ($/°$G_a$) that we call *Transaction Profit*. We calculated entropy by dividing average temperatures as rooms A and B equilibrated into the number of passing joules. We calculate Transaction Profit by dividing Price by the average Buyer and Seller temperatures, as they equilibrate.

In Appendix B, we show more fully how Transaction Profit relates to work done by an economic, Carnot engine.

[63] Heat excites molecules, increasing pressure against a container. Desire heats up people, and puts pressure on behavior.
[64] See also: Study: Your Brain Thinks Money Is A Drug by David Kestenbaum. Nat'l Public Radio August 7, 2009
[65] A Buyer of a horse brings "hot cash", and is literally "hot to trot", eager to "consume". We can also take a Seller's temperature.
[66] Transforming a object into cash is the original "analog to digital" conversion. One might also say that an economic transaction transforms quality into quantity, Being into Becoming, and Essence into Physis.
[67] This correspondence will appear more vividly for some in Appendix B, which presents relevant equations.

Appendix B: Transaction Profits and Carnot Engines

(Under construction)

Transaction Profit: Recall that entropy units are not joules, but "joules per degree". Analogously, there must be, "dollars per average degree Greenspan" in contrast to dollars of profit or $Profit. (See Fig. 2.) In the following, we coin the idea of *Transaction Profit* in $/°$G_a$, and show how the two profits relate. We interpret $\mathbf{T_E}$ or Economic Temperature not as heat, but as tension such as desire or anxiety appearing as Buyer demand.

Fig. 3a shows the T_{Ei} or *Initial Economic Temperature* of a *Buyer* as T_{EBi}. A Seller's T_{Ei} is T_{ESi}.

A horse sells for $200 (Fig. 3b). When a door opens for a sale, dollars flow like joules across a gradient; *dollars flow from Buyer to Seller* across the desire gradient, and release the horse.

Price (d$) thus behaves as the thermoeconomic equivalent of dQ. Demand has transformed "analog" horse into "digital" cash.

Room A lost heat, and cooled. Buyer "lost" cash for horse, and so desire for horse calmed down by a horseworth of cash. Just as room B heated up, Seller fills up with tension. We suspect that something "Seller" rises more than something "Buyer" reduces.

To calculate entropy, we divided units of energy passing between rooms by the average temperature of each room, as it equilibrated. To calculate "profit as entropy", we use the average economic temperature ($\mathbf{T_E}$) between a Buyer and equilibrium, and between a Seller and equilibrium.

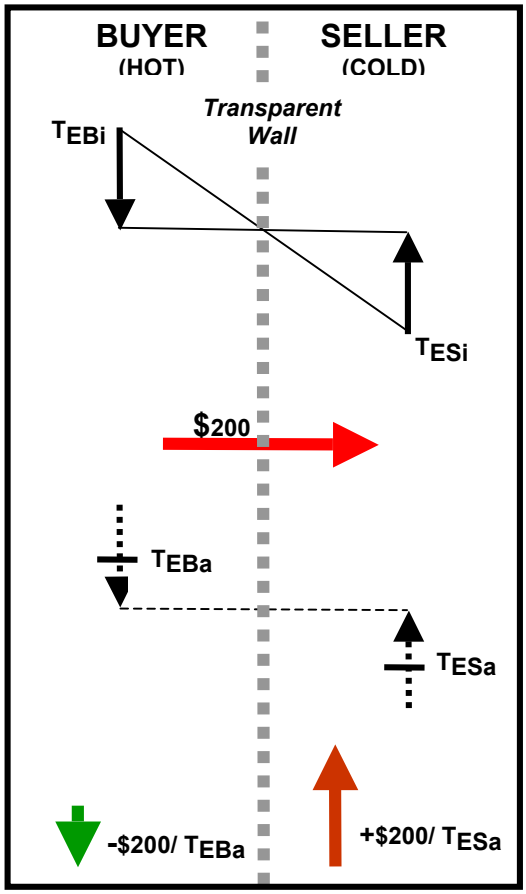

Figure 3

See Fig. 3, c&d. Temperatures equilibrate at point of sale. Thermoeconomic calculations[68] use Average Economic Temperatures ($\mathbf{T_{Ea}}$) calculated between Buyer and equilibrium and between Seller and equilibrium. Buyer's initial temperature is higher than Seller's is, preserving the relation of average temperatures from the dispersive, thermodynamic example. Correspondence between increasing entropy and profit is apparent (Fig. 3d).

Equations will spell out analogies between thermodynamics and economics, and the relation of profit to increasing entropy. We repeat Equation (1), for which we wish to formulate a thermoeconomic equivalent:

$$(1) \qquad \Delta S = dQ/T$$

[68] (Cf. footnote 38) We can even posit an economic heat capacity to discuss the resistance of a hot Buyer to cool down and a cold Seller to warm up. We presume that the heat capacity of a rich Buyer or Seller exceeds that of poorer ones. For simplicity in the calculations, we assume economic heat capacities of the Buyer and Seller to be equal.

As the economic analog of the Second Law, Equation (2) shows the units of profit-entropy as $/degree:

$$(2) \qquad \Delta P = d\$/\ T_{Ea}$$

In Equation (2), the Transaction Profit (ΔP) acts as the Entropy Change *Transaction.* We call it Transaction Profit to distinguish this subjective-objective "hybrid" entropy from the familiar objective quantity, profit measured in $.

We say 'hybrid' because *Transaction Profit* is in *dollars per degree* of economic temperature, and because economic temperature contains a subjective element. We do not have a complete understanding of the implications of Transaction Profit as a subjective-objective hybrid, beyond its function as the psycho-thermo-economic analog to changing entropy. We look forward to returning to consider the issue, however.

More generally, we write the net change of our Buyer-Seller, cash-for-horse as

$$(3) \quad \Delta P\ (\$/°G) = -d\$/\ T_{EBa} + d\$/\ T_{ESa}$$

Equation 3 is an indeterminate equation that we may solve. It relates price, and Buyer and Seller economic temperatures to the transaction profit, for any number of test cases including combinations of objective and subjective components.

Carnot Economics: Heat simply diffusing from room A to B cannot work to power an automobile. Similarly, we recognize that the dissipative Buyer/Seller model cannot account for whatever we might mean by economic work.

Engines convert energy into cycles of work. (Thermodynamics mavens will recall the "Carnot Engine" that Clausius discussed.) Accomplishing economic work will require a model thermoeconomic engine.

We start with a gasoline engine. Gasoline that ignites in a cylinder drives a piston away from its position close to the cylinder top, and provides the working force to spin the drive shaft that turns the wheels. The cylinder returns to the top to receive its next fuel injection, and to begin its next work cycle. A cooling system removes excess heat.

We harness the $200 horse once more to describe an analogous, economic work cycle. The $150 that recovered costs for the Seller restores the "system" to its condition before producing the horse, completing a work cycle, and making "the farm" ready to produce the next horse.

Thus, in a thermoeconomic model, work consists of cash covering costs-to-market including labor and investor costs. *Profit is analogous to excess heat energy*.

Alas, we have not yet sallied forth to take the analogy further into economic engine territory. Please watch this space for further explanation.

Appendix C: Philosophical Notes

(Under construction)

The next paragraphs may be of huge importance, but perhaps of interest only to a few. One may skip them without missing the flow of the monograph.

We have discussed that we describe energy in joules, and entropy in joules-per-degree. Similarly, we may express price in dollars, but profit-as-entropy or "transaction profit" in dollars-per-degree-Greenspan.[69]

You'll recall that economic temperature has a subjective element, but that profit is objective "dollars and cents". The expression of transaction profit in dollars-per-degree-Greenspan thus includes both subjective-temperature and objective-profit numbers. As a result, *economic entropy is a hybrid quantity*. Every economic transaction represents a chimerical combination, an expression of subject-to-object through-put.

Here is our philosophical reward for recognizing economics as asymmetrical thermodynamics rather than as symmetrical Newtonian mechanics. We start to address the mind-body problem debated perhaps since the Pope-Galileo face-off. Perhaps Buyer and Seller are the Complementary aspects of a quantum, economic transaction]

Full abstract of Jaynes paper:
Classical economics was built largely on the analogy to mechanics, as it was known in the time of Adam Smith; particularly the idea of mechanical equilibrium. But a macroeconomic system is in some ways more like a thermodynamic system than a mechanical one, so we develop that analogy. Since the time of J. Willard Gibbs it has been known that prediction of chemical processes { reversible or irreversible { could not possibly have succeeded until the entropy of a macrostate was recognized and taken into account. We conjecture that the same may be true in economics; the direction of economic change may have as much to do with the entropies of neighboring macrostates as with any of the other `dynamical' factors now recognized.

[69] See appendices A, B

Authors

Richard Goldwater, MD

Richard Goldwater graduated from Columbia College and Boston University School of Medicine. He trained in psychiatry at Harvard Medical School.

Dr. Goldwater's training in medicine and long practice of psychiatry have informed his understanding of motivation and interaction in personal and business life. Rather than the traditional doctrines of adaptation or "meaningful relationships", in his view the center of psychology is the creation and gestation of a self-concept from the elements of experience. Psychotherapy serves to assist the birth and the developing life of a "self", as the sum of the life roles one plays for and with others.

At Columbia College in New York City, Dr. Goldwater was careful to balance pre-med science studies with the liberal arts, leading to the conclusion: The Second Law of Thermodynamics is the Rule of Rules, and Shakespeare's *Hamlet* is the Role of Roles. The present document describes the physical world as a set of rules. His forthcoming, "*Marriage Is for Men and Divorce Is for Women"* presents the psychological world as a set of roles.

Dr. Goldwater imbibed increasing entropy at his father's knee. The elder was a distinguished physical chemist who developed market-leading detergent products.

Arthur Jonath, PhD

Arthur Jonath's interest in thermodynamics started with his education in Aeronautics and Astronautics and continued with his graduate work in Materials Sciences. As a sort of vacation from engineering studies while at MIT, he took the Economics Courses 14.01 and 14.02 taught by Paul Samuelson. Not quite the holiday he expected! He learned aircraft control theory from Paul Sandorff and later at Stanford studied thermodynamics under both Dave Stevenson and Walter Harrison. He has used ideas linking these three fields in his technical and management consulting practice.

Dr. Jonath spent the first half of his career in research at the Lockheed Palo Alto Research Laboratories. There he performed R&D on a wide variety of technologies, including solar energy, semiconductors, adhesives and rocket propulsion, and used examples from nature, such as echolocation in whales and compound eyes of dragonflies, in advanced weapons systems designs during the Cold War

Later he was a founder of Visic, a semiconductor start-up, and then VP, Reliability & Quality Assurance for VLSI Technology, Inc. Subsequently he founded Arthur Jonath Associates (AJA) to assist in solving quality, productivity improvement and technology transfer problems. AJA has provided services to a broad range of companies, from start-up to Government Laboratory to Global 500 pharma, electronics and instrument companies.

Dr. Jonath's background also includes grand-scale failure analysis and implementation of customer satisfaction systems. He has served on the board of directors, as CEO or as Technical Advisory board member on several other start-ups. He has taught at the graduate level and was a founding member of the Manufacturing Advisory Board, School of Business, San Jose State University. He currently serves as interim COO and Business Development Director respectively on two technical start-up companies in Silicon Valley and is on the School of Engineering Advisory Board, Stanford University.

Index