THE CHANGING ECONOMIC PARADIGM

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BACKGROUND PAPER 3

CLIMATE CHANGE AND THE FLORIDA KEYS

JULY 21, 2010

SOCIOECONOMIC RESEARCH AND MONITORING PROGRAM

FLORIDA KEYS NATIONAL MARINE SANCTUARY (FKNMS)

NATIONAL ATMOSPHERIC AND OCEANIC ADMINISTRATION (NOAA)

This study was funded by NOAA's Coral Reef Conservation Program

CONTENTS

THE CHANGING ECONOMIC PARADIGM

INTRODUCTION

Greenhouse gas emissions constitute the greatest market failure the world has seen (Stern 2006, p 1; Stern 2009, pp 11-13). This is an important reason why the macroeconomic policy model that guided the United States, Great Britain and other economies over thirty years is being reappraised. The neoclassical economic policy philosophy that became prominent in the 1970s asserted that free markets are self-regulating and governments need not interfere with businesses pursuing their own self-interest. This philosophy is being critically questioned as climate change starts to bite, because it allows major polluting industries to operate without proper environmental control.

Dealing with climate change became progressively more urgent with the mounting evidence that previous climate projections which showed regular and steady rises in emissions did not tell the full story. From 2000 onwards (Cox et al. 2000)[1] climate models have contained *positive feedback loops* incorporating events that can trigger potentially catastrophic change in the global climate – events that have already become visible such as the melting sea-ice, ice caps and thawing permafrost in the Arctic.

There are many references in the recent literature to worst-case scenarios of only a few years ago being exceeded, none more authoritative than NASA's James Hansen and his colleagues (Hansen et al. 2008 is a good example). Hansen only fairly recently criticized his fellow scientists for being reticent when evidence still had a tiny element of uncertainty (Hansen 2007); however, there was no reticence in the synthesis report from the climate change conference of scientists in Copenhagen, Denmark, in March 2009 (Richardson et al. 2009). Its six key messages are stark, uncompromising, and call for urgent action.

The book *Six Degrees* by Mark Lynas (2008) provides a well-researched, readable, and frightening overview of what a warming world might mean to humankind. A recent Australian book (Spratt and Sutton, *Climate Code Red*, 2008) makes a powerful call for emergency action, publicly endorsed by Jim Hansen and other prominent experts.[2]

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[1] This work was pioneered by climate scientists at the Met Office Hadley Centre in Exeter, United Kingdom. The timeline can be further traced back to a previous paper by Met Office's Richard Betts and Peter Cox and two plant scientists from the University of Sheffield which studied climate model feedbacks from changes in vegetation structure (Betts et al. 1997). Unlike Cox et al. (2000), the previous paper only compared the impact on the global mean temperature increase in a limited sense. It found that changes in vegetation structure largely offset physiological vegetation-climate feedbacks in the long term (with some significant regional-scale effects).

[2] The book was followed up by the launch of *Safe Climate Australia* in Melbourne, Australia, in July 2009, by former Vice President Al Gore (http://www.safeclimateaustralia.org/). The new organization is seen as a model for similar groups in other countries to develop whole-of-society plans to restructure economies from fossil fuels to reach "net-zero carbon" at emergency speed. Al Gore had already launched similar ventures in the US, including *Repower America* in 2008, which aims at converting all electricity supplies to clean power (http://www.repoweramerica.org/). The venture is one of several under the auspices of *The Alliance for Climate Protection*, founded by Al Gore in 2006 to alert the global community to the urgent need for comprehensive solutions to the climate crisis. The non-profit, non-partisan Alliance was reported in late 2009 to have more than two million members worldwide (http://www.climateprotect.org/).

The prevalent macroeconomic policy model has also been dealt a blow by the global economic crisis. George Akerlof, joint winner of the 2001 Nobel Prize in economics, and Yale economics professor Robert Shiller, find that the conventional theory is not providing anything like an adequate explanation. Their book is *Animal Spirits: How human psychology drives the economy, and why it matters for global capitalism* (Akerlof and Shiller 2009). The 'animal spirits' were identified by John Maynard Keynes himself in Chapter 12 of his *General Theory of Employment, Interest and Money* (1936); but that part of the Keynesian message was diluted quite rapidly.

As the Florida Keys project entered its second year, it became clearly inappropriate to ignore the economic events of 2008 even if the task of building climate-change scenarios is to take a long-term view. All scenario analysis must address rule-changing issues, and the recession that spread from the United States to the rest of the world is changing macroeconomic thinking and policy. So climate change and the economic crisis both force a reconsideration of economic and financial policy.

This appendix begins with a description of the acknowledged influence of Keynes's "animal spirits" on the business cycle and then proceed to an examination of the new economics of climate change. Because it relates to the current financial and economic downturn we then touch on recent attempts by various scientific disciplines to come to the "aid" of economic theory (mainly on how to predict "bubbles" or fluctuations in confidence affecting stock, residential and other markets).

More important and relevant in the interdisciplinary context, however, is the development of what started as a science-based set of ideas around what Nobel Prize-winning physicist Murray Gell-Mann has called "an emerging synthesis at the cutting edge of inquiry into the character of the world around us – the study of the simple and the complex" (Gell-Mann 1994, p ix). *Complexity theory* in the past two decades has spread across the physical, biological and behavioral sciences, and may have a decisive influence on economic thinking in the future.

Since economics and psychology are both behavioral sciences, recent contributions by psychologists on how to persuade people to accept the urgency of the climate change challenge are also potentially important for the future development of economic theory and its influence on government policy. The American Psychological Association in 2009 published a major report on the subject. As well as warranting a special heading in relation to climate change in this appendix, psychology provides essential understanding of the "animal spirits" in the section below.

The last section but one contains an attempt to pull the three main strands of the analysis together in preparation for the inclusion of economic and financial policy philosophies into the four main scenarios. Climate change policy is then discussed in the final section in the context of the past year's events: the continued impact of the global crisis which began in the United States in 2008, the failure in 2009 to pass emissions trading (ETS) schemes in the USA and other countries including Australia (associated with the general rise of climate change deniers), and the outcome of the UNFCCC Conference of the Parties in Copenhagen in December 2009 (COP-15), which was influenced by these recent developments.

ANIMAL SPIRITS AND THE GLOBAL FINANCIAL CRISIS

THE HEART OF AKERLOF AND SHILLER'S MESSAGE

"The proper role of government … is to set the stage. The stage should give full rein to the creativity of capitalism. But it should also countervail the excesses that occur because of our animal spirits." (pp ix-x)

"The belief that government should not interfere with people in pursuit of their own self-interest has influenced national policies across the globe. … Now, three decades after the elections of Margaret Thatcher and Ronald Reagan, we see the troubles it can spawn. No limits were set to the excesses of Wall Street. It got wildly drunk. And now the world must face the consequences." (p xi)

"With the general acceptance after the 1980s of the belief that capitalism was free-for-all, the playing field may have changed, but the rules of the game had not adapted. This has been nowhere more apparent than in the financial markets. … Public antipathy toward regulation supplied the underlying reason for this failure. The United States was deep into a new view of capitalism. We believed in the no-holds-barred interpretation of the game. We had forgotten the hard-earned lesson of the 1930s: that capitalism can give us the best of all possible worlds, but it does so only on a playing field where the government sets the rules and acts as a referee." (pp 172-173)

ORIGIN AND NEGLECT OF THE ANIMAL SPIRITS

Keynes' General Theory of Employment, Interest and Money

Chapter 12 of the *General Theory* (Keynes 1936), on long-term expectations, is at a "different level of abstraction" from the rest of the book (p 149). An addendum to this appendix summarizes Chapter 12, with Section VII on animal spirits reproduced in full. Basically: "The state of long-term expectation, on which our decisions are based, does not solely depend … on the most probable forecast we can make. It also depends on the *confidence* with which we make this forecast – on how highly we rate the likelihood of our best forecast turning out quite wrong." (p 148)

The uncertainty of long-term forecasting causes investors to rely on a *convention* that the current state of affairs will continue indefinitely, except when there is reason to expect a change. The existing market valuation is considered uniquely *correct* in relation to our existing knowledge of the facts which will influence the yield of the investment. [3]

[3] Akerlof and Shiller are by no means alone in evoking Keynes – the chorus is growing. *The Economist* on October 1, 2009, reviewed three new British-published books under the heading of *The Keynes comeback* (by Peter Clarke: *Keynes: The Twentieth Century's Most Influential Economist*), Robert Skidelsky (*Keynes: The Return of the Master*), and Paul Davidson (*The Keynes Solution: The Path to Global Economic Prosperity*)). The reviewer agrees that "Keynes's disciples are right that their prophet's visions go far beyond the stimulus packages with which his name is now associated" – though it is less clear "what Keynes would have done" in the current economic situation. All three books, however, agree that by "ignoring irreducible uncertainty, modern economics had gone fundamentally off course. Those intellectual errors, in turn, prompted huge policy errors, such as relying on deregulated financial markets." This is also Akerlof and Shiller's fundamental thesis.

The weak points of the convention – relating to what Keynes called the *state of confidence* – are:

1. Real knowledge has declined with the rising influence of stock exchanges which have separated ownership from management – managers know their business; owners of shares have generally no direct knowledge.
2. Ephemeral day-to-day fluctuations in profits "tend to have an altogether excessive, and even an absurd, influence on the market."
3. A conventional valuation based on the mass psychology of "ignorant individuals" can swing violently in the opposite direction as mass opinion fluctuates "due to factors which do not make much difference to the prospective yield."
4. Stock market experts are less interested in making superior long-term forecasts for the benefit of shareholders than in "forecasting changes in the conventional basis of valuation a short time ahead of the general public." (*General Theory,* p 154)

A fifth weak point is the extent of confidence not of the speculative investors themselves but the confidence of the lending institutions towards those who seek to borrow from them (known as the *state of credit*). "A collapse in the price of equities … may have been due to the weakening either of speculative confidence or of the state of credit. But whereas the weakening of either is enough to cause a collapse, recovery requires the revival of *both*. For whilst the weakening of credit is sufficient to bring about a collapse, its strengthening, though a necessary condition of recovery, is not a sufficient condition." (p 158)

Keynes distinguished between *speculation* (the activity of forecasting the psychology of the market) and *enterprise* (the activity of forecasting the yield of assets over their whole life). He found that the influence of speculation on Wall Street is enormous, because Americans tend to buy stock for capital appreciation, whereas the British are (were?) more interested in long-term profit. (p 159)

Human nature, according to the focal Chapter VII, causes activities to depend on spontaneous optimism rather than mathematical expectation. People have a spontaneous urge to act which can only be taken as a result of *animal spirits*. "Enterprise will fade and die if the animal spirits are dimmed and the spontaneous optimism falters … . This means, unfortunately, not only that slumps and depressions are exaggerated in degree, but that economic prosperity is excessively dependent on a political and social atmosphere which is congenial to the average business man." (p 162)

While Keynes is careful not to exaggerate the influence of irrational optimism, he does advocate in his conclusion to Chapter 12 that the State should take "greater responsibility for directly organizing investment." Monetary policy is insufficient: "… the fluctuations in the market estimation of the marginal efficiency of different types of capital, calculated on the principles I have described above, will be too great to be offset by any practicable changes in the rate of interest." (p 164)

How the animal spirits came to be neglected

Akerlof and Shiller note in their preface (p x): "Following the publication of *The General Theory*, Keynes' followers rooted out almost all of the animal spirits – the noneconomic

motives and irrational behaviors – that lay at the heart of his explanation for the Great Depression." One reason was that the aggregate model that Keynes built suited the nascent mathematical subject of econometrics – including his multiplier effect which stipulates that the ultimate impact of an initial increase in income (derived, for example, from increased government expenditure) is a function of the ratio between the marginal propensity to consume (MPC) and the increase in income. Thus, if the MPC is 0.8 because people spend 80% of their increased income and save 20%, the multiplier is 5; if the MPC is 0.5, the multiplier is 2.

This development happened quite quickly led by a group of future Nobel economics prize winners. John R. Hicks published a quantitative interpretation of Keynes' *General Theory* that highlighted a rigid multiplier and the interaction of its effects with interest rates (Hicks 1937).[4] Formal econometric models of total economies followed in the ensuing ten years (Jan Tinbergen from as early as 1936 when he published the world's first econometric model, of the Dutch economy; Lawrence Klein from 1946), as well as the development of national income and expenditure statistics in the 1940s which were tailor-made for econometric databases. Finally, in 1947, another future winner of the Nobel Prize in economics, Paul Samuelson, wrote *Foundations of Economic Analysis*, which more than any other work defined economic theory in mathematical terms and pointed the way to the neoclassical school of economics.

Animal spirits were neglected, and in any case didn't fit well into to the econometric models that became technically possible while computing capacity remained modest.

Neoclassical macroeconomics emerged as a school during the 1970s, which Akerlof and Shiller said did away with whatever animal spirits remained in post-Keynesian thought (p x). We cannot hope to give justice to a major new economic school in a few sentences, and there are survey papers (such as Hoover 2008) which provide comprehensive descriptions. The following will have to suffice.

Neoclassical economics tried to explain consumption, investment, the demand for money and other elements of the aggregate Keynesian model in a manner consistent with the classical microeconomic assumption that individual and firms behave optimally. 'Optimally' implies 'rationally'. This means, among other things, that economic decisions by individuals and firms are based on real rather than nominal or monetary factors (there is no "money illusion"), and that they generally hold on to their rational expectations. In other words, Keynesian animal spirits were dismissed as insignificant or irrelevant.

This takes us to the situation today, when the economic crisis has hit home, and to Akerlof and Shiller's analysis.

[4] In the 1937 paper, Hicks invented the so-called IS/LM model to formalize Keynes' General Theory. IS originally stood for investment-savings equilibrium but came to represent the locus of all equilibria where total spending (consumption plus planned investment plus government purchases plus net exports) equals total output or GDP. LM (LL in the Hicks paper) represented the role of finance and money, showing the equilibrium between liquidity preference (the preference for holding cash balances rather than securities) and the money supply. (http://en.wikipedia.org/wiki/IS/LM_model).

Five expressions of animal spirits

Akerlof and Shiller identify *confidence*, *fairness*, *corruption and antisocial behavior*, *money illusion*, and *stories* as expressions or aspects of animal spirits that economists should acknowledge (pp 5-6):

1. "The cornerstone of our theory is *confidence* and the feedback mechanisms between it and the economy that amplify disturbances." [They describe the "confidence multiplier" on pp 14-15.]
2. The setting of wages and prices depends largely on concerns about *fairness.*
3. We acknowledge the temptation toward *corrupt and antisocial behavior* and their role in the economy.
4. *Money illusion* is another cornerstone. The public is confused by inflation or deflation and does not reason through the effects. [Compare the neoclassical macroeconomics described above.]
5. Finally, our sense of reality, of who we are and what we are doing, is intertwined with the story of our lives and of the lives of others. The aggregate of such *stories* is a national or international story, which itself plays an important role in the economy."

Each of these can be used to contrast standard economic theory and real behavior, as summarized in Figure 1 which contrasts conventional macroeconomics with models that take animal spirits into account:

Confidence: "When people make significant investment decisions, they must depend on confidence. Standard economic theory suggests otherwise. It describes a formal process for making rational decisions: People consider all the options available to them. They consider the outcomes of all these options and how advantageous each outcome would be. They consider the probabilities of each of these options.

Figure 1: Two views of macroeconomics

Conventional economics	Plus animal spirits
CONFIDENCE Decisions are based on weighting probability of each outcome	Not based on rational decisions. Confidence is the first and most crucial of the animal spirits
FAIRNESS Large economic literature but fairness traditionally seen as secondary factor	Basic economic activities including wage and price fixing need fairness as part of explanation
CORRUPTION/BAD FAITH Conventional economics based on maximizing profits is basically amoral	The business cycle is influenced by fluctuations in poorly controlled predatory activity
MONEY ILLUSION Price & wage decisions are driven by real, not nominal values	People are unable to see through the veil of inflation and for example, avoid using indexation
STORIES Economists prefer quantitative facts and figures for optimization	Epidemics of confidence or lack of confidence based on 'stories' have real effects on markets

Source: Akerlof and Shiller (2009), Part 2: *Animal Spirits*

And then they make a decision.

But can we really do that? Do we really have a way to define what those probabilities and outcomes are? Or, on the contrary, are not business decisions ... made much more on the basis of whether or not we have confidence? … [At] the level of the macroeconomy, in the aggregate, confidence comes and goes. Sometimes it is justified. Sometimes it is not. It is not just a rational prediction. It is the first and most crucial of our animal spirits." (pp 13-14)

***Fairness*:** "Considerations of fairness are a major motivator in many economic decisions and are related to our sense of confidence and our ability to work effectively together. Current economics has an ambiguous view of fairness. While on the one hand there is a considerable literature on what is fair and unfair, there is also a tradition that such considerations should take second place in the explanation of economic events.

We insist that if such motivations are to be given lower status in economic argument, then justification must be given. On the contrary, we think phenomena as basic as the existence of involuntary unemployment and the relation between inflation and aggregate output can be easily explained when fairness is taken into account." (p 25)

***Corruption and bad faith*:** "If we wish to understand the functioning of the economy, and its animal spirits, we must also understand the economy's sinister side – the tendencies toward antisocial behavior and the crashes that disrupt it at long intervals or in hidden places." (p 26)

"The usual symbols of what makes capitalism work are the go-get-'em CEOs who pride themselves on being aggressive and tough risk-takers. … But it is precisely because there are these CEOs, so unapologetic about making a buck for themselves and their companies, that there is a need for a counterbalance, to ensure that all of this energy does not spill over into dishonesty. This counterbalance comes in the form of accountants, so well known for their stable personalities and their probity. … They are the cool-minded sheriffs of its Wild West." (p 29)

Unfortunately this is not always so, and what follows suggests that the authors were rather tongue-in-cheek in the above passage, or at least that there are some gross exceptions to their rule. The Savings & Loans (S&L) Associations in the United States act as banks that lend money primarily for mortgages. "Clever accounting practices" were instituted to allow the S&Ls to stay in business in the 1980s when they should have been technically bankrupted – the fact that they were not was exploited by the "junk bond impresario Michael Milken" who became the most inventive user of "S&L sweetheart money" (described in detail on pp 30-32). "The S&L crisis was ultimately responsible for a considerable amount of the economic turmoil that disturbed the economy during the recession of 1990-91 and for the slow recovery that followed it, lasting until 1993." (p 32)

During the 2001 recession, Enron's accountants, one of the then "big five" accounting firms, Arthur Andersen, failed to blow the whistle on the fraudulent practices that proliferated. "They were afraid that if they did so they would lose the rich consulting contracts that Enron was also giving them. It was yet another sweetheart deal. An economist would describe this situation as an equilibrium. Everyone was following his own self-interest. But the public was

buying snake oil. The recession of 2001 offered ample evidence that this equilibrium was by no means mutually beneficial for all concerned." (p 35)

The three recent recessions in the United States – 1990-91, 2001, and the current one set off by the subprime crisis of 2007 and precipitated by the Lehman Brothers collapse in September 2008 – provide examples of changes in the nature of predatory activity. "These examples illustrate that the business cycle is connected to fluctuations in personal commitment to principles of good behavior and to fluctuations in predatory activity, which in turn is related to changes in opportunities for such activity.

Why do new kinds of corrupt or bad-faith behavior arise from time to time? Part of the answer is that there are variations through time in the perceived penalties for such behavior. … In a time of widespread corrupt activity, many people may get the impression that it is easy to get away with it." (p 38)

Money illusion is "another missing ingredient in modern macroeconomics. Money illusion occurs when decisions are influenced by nominal dollar amounts. Economists believe that if people were "rational" their decisions would be influenced only by what they could buy or sell in the marketplace with those nominal dollars. In the absence of money illusion, pricing and wage decisions are influenced only by relative costs or relative prices, not by the nominal values of those costs or prices." (p 41)

"We have seen that one of the most important assumptions of modern macroeconomics is that people see through the veil of inflation. That seems to be an extreme assumption. It also seems totally implausible given the nature of wage contracts, of price setting, of bond contracts, and of accounting. These contracts could easily throw aside the veil of inflation through indexation. Yet the parties to the contracts in most cases choose not to. And these are but a few indications of money illusion. We shall see that taking money illusion into account gives us a different macroeconomics – one that arrives at considerably different policy conclusions. Once again animal spirits play a role in how the economy works." (p 50)

Stories**:** "The human mind is built to think in terms of narratives, of sequences of events with an internal logic and dynamic that appear as a unified whole. In turn, much of human motivation comes from living through a story of our lives, a story that we tell to ourselves and that creates a framework for motivation. … The same is true for confidence in a nation, a company, or an institution. Great leaders are first and foremost creators of stories." (p 51)

"It is generally considered unprofessional for economists to base their analysis on stories.[5] On the contrary, we are supposed to stick to the quantitative facts and theory – a theory that is based on optimization, especially optimization of economic variables. Just the facts, ma'am. There is good reason to be careful about the use of stories. The news media are,

[5] *What about our scenarios if stories are considered an unacceptable economic tool?* Stories are at the root of the scenario analysis which is the end product in the Florida Keys project. But the IPCC scenarios represent carefully constructed possible alternative future worlds chosen to set the boundaries of what is regarded as plausible – they describe the credible range of what might happen in an unpredictable future. Scenario analysis represents a recognized approach to test what may plausibly happen – complemented by quantitative future estimates of selected socioeconomic, demographic, and biophysical variables. Their connection with real policy is solely through the recommendations that follow at the end of the study. The premises are there for all to see and assess, and do not lead to an "epidemic of stories" serving particular vested interests.

after all, in the business of creating stories that people would like to hear. Thus there is a tendency toward overexplanation of economic events. Just look at the theories offered by pundit after pundit on a slow news day when stocks have moved by a fair amount. Thus economists are rightly wary of stories and of the reality they seek to define." (p 54)

The stories, however, may themselves move markets, have real effects. We can have epidemics of stories as much as epidemics of disease. "Just as epidemics spread through contagion, so does confidence, or lack of confidence. Indeed confidence, or the lack thereof, may be as contagious as any disease. Epidemics of confidence or epidemics of pessimism may arise mysteriously simply because there was a change in the contagion rate of certain modes of thinking." (p 56)

Eight key questions and the influence of animal spirits

Part 2 of *Animal Spirits* (pp 57-166) poses eight fundamental questions, all relevant in the context of animal spirits but beyond the scope of this appendix:

1. Why do economies fall into depression?
2. Why do central bankers have power over the economy?
3. Why are there people who cannot find a job?
4. Why is there a trade-off between inflation and unemployment in the long run?
5. Why is saving for the future so arbitrary?
6. Why are financial prices and corporate investments so volatile?
7. Why do real estate markets go through cycles?
8. Why is there special poverty among minorities?

"The real problem … is the conventional wisdom that underlies so much of current economic theory. So many members of the macroeconomics and finance profession have gone so far in the direction of "rational expectations" and "efficient markets" that they fail to consider the most important dynamics underlying economic crises. Failing to incorporate animal spirits into the model can blind us to the real sources of trouble.

The crisis was not foreseen [by bureaucrats and politicians] … because there have been no principles in conventional economic theories regarding animal spirits. Conventional economic theories exclude the changing thought patterns and modes of doing business that bring on a crisis. They even exclude the loss of trust and confidence. They exclude the sense of fairness that inhibits the wage and price flexibility that could possibly stabilize an economy. They exclude the role of corruption and the sale of bad products in booms, and the role of their revelation when the bubbles burst. They also exclude the role of stories that interpret the economy. All of these exclusions from conventional explanations of how the economy behaves were responsible for the suspension of disbelief that led up to the current crisis. They are also responsible for our current failure in knowing how to deal with the crisis now that it has come." (p 167)

"It is necessary to incorporate animal spirits into macroeconomic theory in order to know how the economy really works. In this respect the macroeconomics of the past thirty years

has gone in the wrong direction. In their attempts to clean up macroeconomics and make it more *scientific*, the standard macroeconomists have imposed research structure and discipline by focusing on how the economy would behave if people had only economic motives and if they were also fully rational." (p 168)

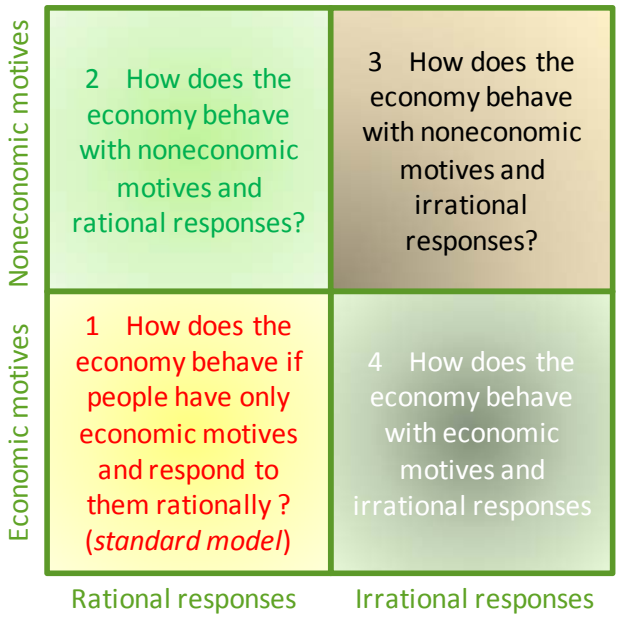
This is the model depicted by the lower left quadrant of Figure 2, drawn from the text of page 168 of *Animal Spirits*. Akerlof and Shiller advocate a description of all four quadrants combining economic versus noneconomic motives and rational versus irrational responses. They conclude:

"We believe that the answers to the most important questions regarding how the macroeconomy behaves and what we ought to do when it misbehaves lies largely (though not exclusively) within those three blank boxes." (p 168)

Akerlof and Shiller use events since 2000 as a test, noting that it is in a nutshell what happened toward the current financial crisis (pp 169-170):

- In the stock market crash in 2000 "the economy recoiled from the irrational exuberance of the dot-com years."
- Overconfidence took hold in the housing boom from 2001 to 2005: "People began to buy housing as if this were their last chance ever to buy a house .. and speculators began to make investments in housing, as if other people were going to think that they should buy now, at almost any price, because they would not be able to afford to buy a house later."

Figure 2: Extending the macroeconomic model



Source: Akerlof and Shiller (2009), p 168 text: 'How macroeconomic theory must respond'

- "The financial markets – which are supposed to be so cautious – aided and abetted the process. Of course, the real estate dealers and the mortgage brokers had no reason to dampen the fever. They were collecting [enormous] transaction fees. .. Most surprisingly, those on the other side of the ledger took in those mortgages and gave the home buyers the massive funds they needed for their unwise speculations."
- "The rating houses based their estimates of the probability of default of mortgages .. on recent trends in home prices – and those had always gone up. So there appeared to be little reason to fear default in this case. Even if someone in a rating agency had thought

that the opposite was true – that the ratings should also incorporate the possibility that home prices might decline – anyone who actually blew the whistle would make herself immensely unpopular by casting aspersions on the whole parade of fee collectors who were getting so rich so quickly."

STIGLITZ AND OTHER ECONOMISTS ON A PARALLEL COURSE

One of Akerlof's two fellow Nobel Prize economics winners in 2001, Joseph Stiglitz, invoked Keynes' animal spirits in his review of the East Asia crisis in 1997-98 in *Globalization and Its Discontents* (2002). "Capital market liberalization made the developing countries subject to both the rational and the irrational whims of the investor community, to their irrational exuberance and pessimism. Keynes was well aware of the often seemingly irrational changes in sentiments. … [He] referred to these huge and often inexplicable swings in mood as "animal spirits." Nowhere were these spirits more evident than in East Asia." (p 100)

The general thesis in Stiglitz's book, based on his experience as chairman of President Clinton's Council of Economic Advisers and chief economist for the World Bank in the 1990s, is a failure of globalization in much of the developing world. "Globalization today is not working for many of the world's poor. It is not working for much of the environment. It is not working for the stability of the global economy." (p 214)

In response to the global recession in late 2008, Joseph Stiglitz was appointed chairman of a United Nations committee to advise on reform of the international monetary and financial system. He notes in his introductory remarks (Stiglitz 2009): "Seventy five years ago Keynes explained why markets are not self-correcting, at least in the relevant time frame. Even when markets were Pareto efficient,[6] of course, there was no assurance that what resulted conformed to any principles of social justice—either in terms of outcomes or opportunities. More recently, theories of behavioral economics have uncovered patterns of human behavior in which individuals and groups exhibit systematic irrationalities. Yet, while there was mounting theoretical and empirical evidence concerning the appropriate domains for government intervention, some pushed an agenda downplaying the role of government, including deregulation. The success of this agenda suggests that some of the problems the world faces today can be viewed as much a problem of governance and politics as a failure of economics."

In his review of the state of financial services for *The Economist*, one of Edward Carr's papers (2009) is titled *Wild-animal spirits*. "Whenever issuers compete for market share or buyers pile in because they are afraid of missing the boat, a boom may be in the making. Investors herd together in this way because, as John Maynard Keynes argued, they do not have a sure grasp of the future. Faced with uncertainty, they resort to whatever conventions they can find to cling to, from popular wisdom to new theories. In a boom, overconfident investors take on bets that they later find themselves unable to discharge." Animal spirits displayed once more.

[6] Informally, Pareto efficient situations are those in which any change to make any person better off would make someone else worse off. (Wikipedia)

UCLA economics professor Roger Farmer has actually tried building animal spirits into a formal economic model. He concludes that the question whether business cycles are driven by animal spirits "is likely to remain a lively and important focus of research for some time to come." (Farmer 2007, p 10).

He notes that Keynes has once again become fashionable as the world economy spirals into recession. A main aspect of animal spirits is the assumption that "confidence" is an independent fundamental determinant of economic activity (Farmer 2009, p 10). He goes as far as using "confidence" interchangeably with "animal spirits" and believes that confidence determines what Keynes called "the state of long-term expectations." (p 17)

A STRATEGIC BUSINESS VIEW OF THE CRISIS

"Management lessons from the financial crisis" (Webb 2009) reflects the views of two leading business strategists, Lowell Bryan of McKinsey's New York office and UCLA strategy professor Richard Rumelt. It reflects on the broad managerial implications of the crisis. There is no mention of animal spirits but they obviously lurk. This is from the microeconomic coalface which was first ignored by macroeconomists, and then treated as if individuals and firms behaved rationally. This mistake is unlikely to be repeated for a decade or more, though the lesson may be once again forgotten as the century rolls on.[7]

Rumelt notes a dramatic failure in management governance. He calls it the "smooth sailing" fallacy, referring to the *Hindenburg* airship that did hundreds of successful and comfortable flights before it burst into flames unexpectedly over New Jersey in May 1937. The ride in the *Hindenburg* was smooth until it exploded. "If you had a modern econometrician on board, no matter how hard he studied those bumps and wiggles in the ride, he wouldn't have been able to predict the disaster. The fallacy is the idea that you can predict disaster risk by looking at the bumps and wiggles in current results. … The history of bumps and wiggles – and of GDP and prices – didn't predict economic disaster. … What happened to the *Hindenburg* that night was not a surprisingly large bump. It was a design flaw."

"This smooth-sailing fallacy arises when we mistake a measure for reality. Competent management always looks deeper than the numbers, deeper than the current measures. Incompetent management just focuses on the metrics, on the body count, on quarterly earnings – or on GDP growth or the consumer price index. And that's how we get into these troubles."

Looking beyond the numbers at the deeper issues is invoking animal spirits, though these are left unmentioned. Animal spirits controlled by competent managers are important for business success, and ultimately for the success of our capitalistic system. The animal spirits

[7] The lesson may be forgotten in less than a decade, unless there is an institutional change in the way the financial information is analyzed and promulgated. Between 1985 and 2009, financial analysts were persistently overoptimistic; their forecasts were almost 100% too high on average. A 5-year rolling average of earnings growth for the S&P 500 companies showed little relationship between forecasts ranging between 11 and 18% (the latter associated with the high-tech or "dot-com" bubble from 1995 to 2000). Compared with an average of 7% for actual earnings, the analysts' forecasts averaged 13% for the 25 years. Furthermore, the forecasts become even less accurate as economic growth declines and analysts are slow to adjust to reality. The 5-year average forecast by analysts for 2004-09 was about 12%, but the actual figure, at -2%, turned negative for the first time in the 25 years (Goedhart et al. 2010, Exhibit 2). The previous low point, associated with the "dot-com" bubble, showed the actual average for 1997-2002 decline to 1%, compared with the analysts' forecast of nearly 14%.

that led to the "smooth sailing" fallacy are more damaging. But macroeconomic thinking can no longer ignore them.

Lowell Bryan sums up his version of the fallacy: "One of the other things that really characterized the period from about 1982 until literally last year was that economic volatility – in terms of degree and depth of business cycles – and financial volatility measurably declined. Basically, people assumed they were always going to have flat seas. There weren't going to be storms. And they built up a set of business practices and strategies which may have had really deeply flawed assumptions, as Richard was saying. A lot of people do things because if it's been good for the last three years, they assume it's going to be good for another year.

I think that we are now into a period where whole generations of people – consumers, managers – who had been lulled into the view that the world was not volatile, now know in their gut that it is in a way that you couldn't describe to them before. And I think that's going to have unknown behavioral effects and unknown economic effects."

SCIENTISTS OFFER TO RE-DEFINE ECONOMIC THEORY

The alleged failure of conventional economic theory to recognize 'animal spirits' has renewed suggestions from the natural sciences that their input might be helpful and maybe even decisive. Some scientists claim that emerging market bubbles can be detected through the mathematical patterns they generate, even suggesting that seismological techniques may help calculate the likely frequency of market fluctuations. That is not an idle claim; mathematical "power curves" have been shown to describe a wide range of both natural and economic phenomena, where a short "head" of frequently occurring small events drops off to a long "tail" of increasing rare but much larger ones (Zanini 2009).[8] The issue is how these distributions can be used to predict actual events like the global financial crisis.

Economists Robert Shiller and Karl Case comment that "purely mathematical approaches have a big drawback: the irrational response of people. In any bubble, those making big profits will find arguments as to why this time the underlying maths should be different. Before the dot-com bubble burst in 2000, the reasoning was that the Internet had created a "new economy"; in the build-up to the current crisis, people said that financial engineering had made mortgage risk a thing of the past." (Buchanan 2009, p 34)

The efforts by scientists reported above are part of an interdisciplinary research field named *econophysics* in the mid-1990s, referring to the work of several physicists working in the area of statistical mechanics. They decided to tackle the complex problems of uncertain or

[8] Power laws are currently being applied to weather forecasting (possibly capable of being expanded to climate modeling), based on the observation that patterns in nature repeat themselves at different scales from very large to very small (a feature of the "fractals" in chaos theory). The problem has been that the power curves developed here typically need more than one exponent, but the scientists involved, led by Shaun Lovejoy, are now reported to be working with NOAA in Boulder, Colorado, on incorporating multifractal techniques into live computer models of the atmosphere, with the aim of making both weather and climate models reliable at the finest scale possible. If successful, this would eventually reduce the high uncertainty in climate modeling, though "it may take some years before the techniques are implemented." (Matthews 2009)

Power laws are related to Martin Weitzman's "fat-tailed" distributions in which the tail probability approaches zero more slowly than exponentially (Weitzman 2009).

stochastic processes and nonlinear dynamics typically posed by stock market fluctuations. Papers on econophysics have been published primarily in journals devoted to physics and statistical mechanics, rather than in leading economics journals. Mainstream economists are reported to have been generally unimpressed by this work.[9] There is, however, more to this than meets the eye, as reported in the section on genuine interdisciplinary influences, below, with reference to the role of econophysics in complexity economics.

Economics itself may have become overly mathematical and driven by the neoclassical model over the past half-century, and needs to stand back and look at its basic assumptions. There are signs that this is happening. The debate on the inadequacies of economic theory intensified during 2009, and subsequent sections show that serious re-evaluation is underway led by economists who were already engaged in a deep reassessment of their discipline. The insights from other branches of learning are important but the remedies must be defined within what is after all a well-established social science in its own right. That said, a growing number of economists agree that the "supply-side economics" advocated in the Reagan and Thatcher years, holding that reducing tax rates for businesses and wealthy individuals stimulates savings and investment for the benefit of everyone through "trickle-down" effects, and the markets being freed from regulations, has led the world down a dangerous path.

Two other theories buttressed supply-side economics: "rational expectations" and the "efficient market" hypothesis, proclaiming that traders do not make systematic errors when predicting the future, and that the prices of shares, bond and physical property accurately reflect all relevant information. Biochemist Terence Kealey (2009) rightly queries such precepts of conventional economic theory.

Kealey's main thesis is more debatable, that science is technology-driven and technology is profit-driven and that science is therefore not in need of government funding. Science is ostensibly regarded by economists as a public good in the sense that its results are generally accessible – causing alleged *market failure* because no private company will pay for research when its benefits go to others. In the real world, however, billions of research-and-development dollars are expended by major corporations in the pursuit of financial profitability, benefiting from the time lag before competitors can catch up with what Kealey calls the relevant tacit knowledge of the innovators, as well as the constraining influence of intellectual property regulations, and the cost to competitors of copying innovations, employing scientists, and building the necessary infrastructure.

The issue is critical in the context of the greatest market failure, climate change, the economics of which is taken up in the next main section. To have governments withdraw from supporting the funding of the big transition needed to go from fossil to renewable energy, and the rest, would verge on the suicidal. The climate change predicament highlights the distinction between scientific and technological research undertaken for purely commercial motives and the research needed to underpin renewable energy and other technologies which will start to prosper only under strong and determined public policy

[9] From http://en.wikipedia.org/wiki/Econophysics, accessed September 23, 2009. The judgment may be unduly harsh, though some efforts quoted in the present section appear to be more than a little naïve.

leadership and in conditions of reduced market failure and other political and commercial obstacles. Kealey fails to make that distinction.

NEW ECONOMICS OF UNCERTAINTY AND RISK

Economists are working to meet the challenges outlined in the previous section, with some sophisticated responses on the treatment of risk. Professor Andrew Lo leads the Laboratory for Financial Engineering at the MIT Sloan School of Management. It is described as "a partnership between academia and industry designed to support and promote quantitative research in financial engineering and computational finance." [10]

Lo and Mueller (2010) note: "The quantitative aspirations of economists and financial analysts have for many years been based on the belief that it should be possible to build models of economic systems – and financial markets in particular – that are as predictive as those in physics." The book that perhaps more than any other contributed to the demise of Keynesian "animal spirits" in economic theory, Paul Samuelson's *Foundations of Economic Analysis* (1947), was itself heavily influenced by the mathematician and polymath scientist Edwin Bidwell Wilson, whose mathematical economics seminar he attended in 1935-36. "I was vaccinated early to understand that economics and physics could share the same formal mathematical theorems, .. while still not resting on the same empirical foundations and certainties." (Samuelson 1998, p 1376)[11]

The contrast with physics motivated Lo and Mueller to propose a "taxonomy of uncertainty" – a continuum ranging from "Level 1" (complete certainty) through "risk without uncertainties", "fully reducible uncertainty" and "partially reducible uncertainty" to "Level 5" (irreducible uncertainty, which "cannot be modeled quantitatively, yet has substantial impact on the risks and rewards of quantitative strategies"). They suggest that physicists rarely venture as far as "Level 4" (partially reducible uncertainty), but that "in this respect, economics may have more in common with biology than physics."

The financial crisis, according to Lo and Mueller (2010) "has re-invigorated the longstanding debate regarding the effectiveness of quantitative methods in economics and finance. Are markets and investors driven primarily by fear and greed that cannot be modeled, or is there a method to the market's madness that can be understood through mathematical means"?[12] They attempt to reconcile the two sides of the debate tracing the intellectual origins of the conflict to what they call "physics envy." "The quantitative aspirations of economists and financial analysts have for many years been based on the belief that it

[10] http://lfe.mit.edu/about/intro.htm.

[11] Samuelson added that he was perhaps Wilson's only disciple ((1998, p 1376). One of the three other economists attending the seminar was Joseph Schumpeter, more than 30 years Samuelson's senior, on whom the mathematical "vaccination" worked differently if at all (see Hoegh-Guldberg (2010d) on Schumpeter's profound influence on the modern theory of technology). The others were Samuelson's contemporaries (around 20 years old at the time and also destined for fame) Abram Bergson and Sidney Alexander.

[12] This seems to contrast with Shiller's and Case's view in the previous section (as reported in Buchanan 2009), but the difference may be more apparent than real in view of Lo and Mueller's taxonomy of uncertainties and their subsequent comments reported in the above text.

should be possible to build models of economic systems that are as predictive as those in physics."

They conclude that just as scientific principles are compact distillations of much more complex phenomena, specific subject areas of economic theory capture an expansive range of economic phenomena, despite their seemingly simplistic assumptions. "However, any virtue can become a vice when taken to an extreme, particularly when that extreme ignores the limitations imposed by uncertainty. .. In this respect, the state of economics may be closer to disciplines such as evolutionary biology, ecology, and meteorology."

"So what does this imply for the future of finance? Our hope is that the future will be even brighter because of the vulnerabilities that the recent crisis has revealed. By acknowledging that financial challenges cannot always be resolved with more sophisticated mathematics, and incorporating fear and greed into models and risk-management protocols explicitly rather than assuming them away, we believe that the financial models of the future will be considerably more successful, even if less mathematically elegant and tractable. Just as biologists and meteorologists have broken new ground thanks to computational advances that have spurred new theories, we anticipate the next financial renaissance to lie at the intersection of theory, practice, and computation."

An earlier paper on "the origin of behavior" (Brennan and Lo 2009) proposes "a single evolutionary explanation for the origin of several behaviors that have been observed in organisms ranging from ants to human subjects, including risk-sensitive foraging, risk aversion, loss aversion, probability matching, randomization, and diversification."

The evolutionary origin of behavior has important implications for economics. "Specifically, much of neoclassical economic theory is devoted to deriving the aggregate implications of individually optimal behavior, i.e., maximization of expected utility or profits subject to budget or production constraints. By documenting departures from individual rationality, behavioral critics argue that rational expectations models are invalid and irrelevant. Both perspectives are valid but incomplete."

"Animal behavior is, in fact, the outcome of multiple decision making components .. that each species has developed through the course of evolution. What economists consider to be individually rational behavior is likely to emanate from the prefrontal cortex, a relatively new component of the brain on the evolutionary timescale, and one that exists only in *Homo sapiens* and certain great apes." However, the human brain also contains considerably older structures linked to primitive and aggressive responses. "In the face of life-threatening circumstances, even the most disciplined individual may not be able to engage in individually rational behavior thanks to adaptive "hard-wired" neural mechanisms that conferred survival benefits to the species (and not necessarily to any given individual)."

"A better understanding of this pattern may allow consumers, investors, and policymakers to manage their risks more effectively. .. In short, the behaviors derived in our evolutionary framework may well be the "animal spirits" that Keynes .. singled out seven decades ago, and which is apparently still a force to be reckoned with today."

The behavioral research by Andrew Lo and his colleagues is interesting not only by pointing a way forward for important parts of economic theory, but also for showing the links with

natural science, contrasting a past influence from physics on the leading economic research of the 1940s with the observation that "the state of economics may be closer to disciplines such as evolutionary biology, ecology, and meteorology. .. And for the truly global challenges such as climate change, the degree of subjectivity and uncertainty gives rise to spirited debate, disagreement, and what appears to be chaos to uninformed outsiders. Should we respond by discarding all forecasting models for predicting rainfall, or should we simply ignore the existence of hurricanes because they fall outside our models?

Perhaps a more productive response is to delineate the domain of validity of each model, to incorporate this information into every aspect of our activities, to attempt to limit our exposure to the catastrophic events that we know will happen but which we cannot predict, and to continue developing better models through data collection, analysis, testing, and reflection, i.e., becoming smarter." (Lo and Mueller 2010)

Commenting in *Nature* on this work, Phillip Ball (2010) notes that the classification of uncertainty into five levels is not unlike Donald Rumsfeld's distinction (quoted in Appendix 3) between things we know we know, things we know we don't know, and things we don't know we don't know ("unk-unks"). "It is one thing to recognize the gaps and uncertainties in our knowledge of a situation, and another to acknowledge that unforeseen circumstances might entirely change the picture. The economy is .. prone to .. unknown unknowns – but economic decision making is commonly misled by confusing them with known unknowns. Financial speculation is risky by definition. Yet the danger is not that the risks exist but that the highly developed calculus of risk in economic theory — for which Nobel prizes have been awarded — gives the impression that the risks are under control." (Ball 2010)

Recognizing the five levels of uncertainty, "risk assessment in economics can be united with the way uncertainties are handled in the natural sciences. It may then become clearer where conventional economic theory is a reliable guide to planning and forecasting, and where its predictive value fails." "Economists should recognize the existence of uncertainty that their models can't capture. Economists have known since the 1960s that fluctuations in commodity prices are different. They don't fit a Gaussian distribution but are 'fat-tailed', meaning that they have a greater proportion of big deviations, compared with a bell curve. Even so, many standard economic theories have failed to accommodate this deviation from the Gaussian form .. ." (Ball 2010)

ECONOMICS OF CLIMATE CHANGE

The foremost proponent in shaping climate change economics is Lord Stern, author of the *Stern Review on Climate Change* for the British Treasury (Stern 2006). Nicholas Stern was chief economist and senior vice president of the World Bank before becoming head of the Government Economic Service in the United Kingdom and Second Permanent Secretary at the UK Treasury. In 2007, after his review, he was appointed to the I. G. Patel Chair of Economics and Government at the London School of Economics. He followed the *Review* with a very readable "blueprint for a safer planet" (Stern 2009).

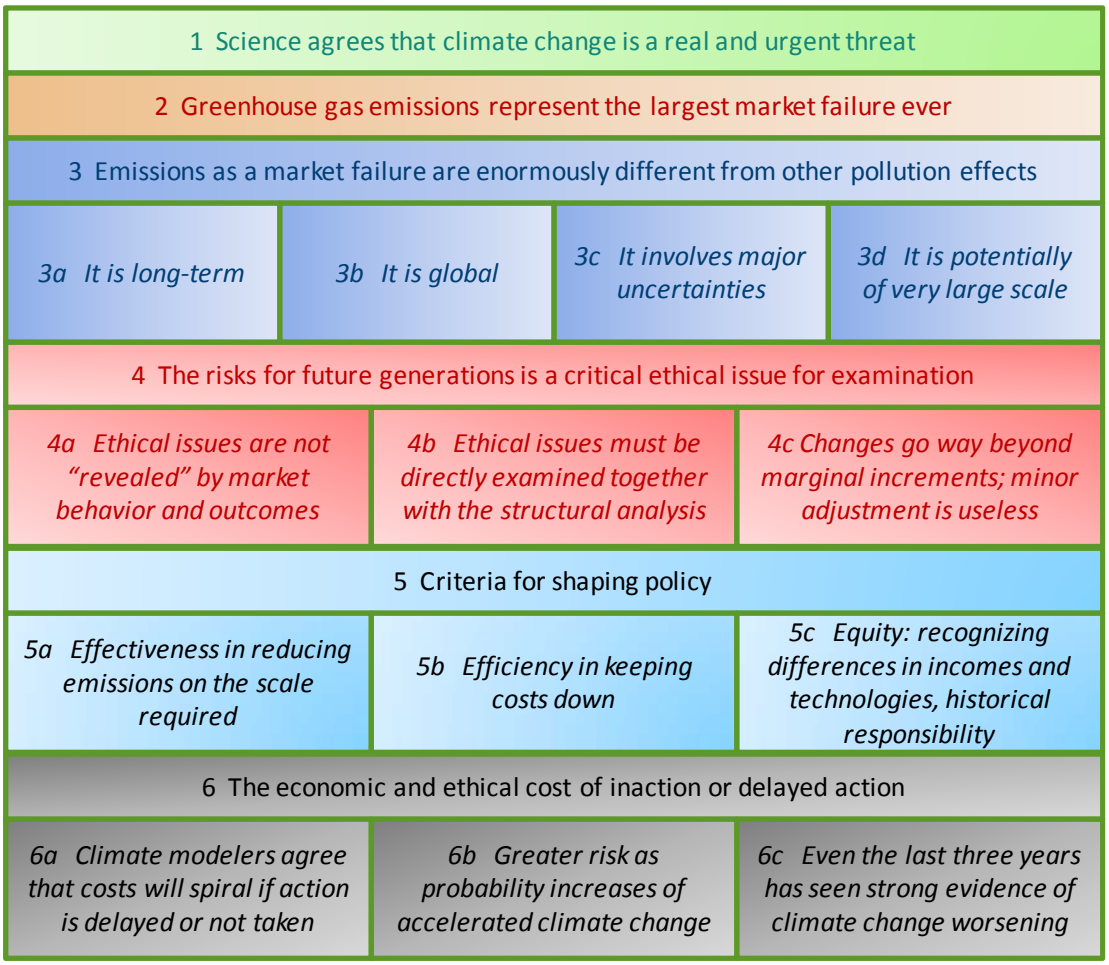
Before getting involved in climate change economics in 2005, Stern had built up a career-long interest in what he calls the second great challenge of the 21st century: fighting poverty, particularly in Africa. This background is important for the understanding of his work on

climate change, because he sees a close connection between the two: "The two greatest problems of our times – overcoming poverty in the developing world and combating climate change – are inextricably linked." (Stern 2009, p 8)

Other economists have taken an interest in and contributed to the development of the economics of climate change. The Asian Development Bank published a major study in April 2009 listed in the references at the end of this appendix. Stern wrote the foreword. Professor Ross Garnaut published a major review for the Australian Government in September 2008 which also questions the conventional macroeconomic model.[13]

No one to date, however, has developed the theory more comprehensively than Stern. Between the *Review* and the 2009 book he repeatedly commented that he was unduly

Figure 3: Economics of climate change



Source: Stern (2006, 2009 – in particular 2009 Chapters 1 and 5)

[13] Garnaut lists four benefits from mitigation to climate change (Hoegh-Guldberg 2010a). Two are actually or potentially measurable in GDP terms, and one is the insurance value from mitigation – how much are you prepared to pay to avoid a small risk of highly damaging outcome? The fourth is non-market impacts, always difficult to quantify. Garnaut postulates a utility function rising with conventional goods and services but also with environmental amenity, like the value placed on the integrity of coral reefs and other landscapes, genetic diversity and so on.

The impact of market benefits is relevant for the way the future is valued relative to the present. In terms of the pure value of time preference, the discount rate used to value future versus present should be near zero, but this is tempered to the extent future generations are likely to be richer than ours. Garnaut agrees fully with Stern that a business-as-usual scenario will lead to a very bad situation.

optimistic when he wrote the review. This includes his Richard T. Ely lecture to the American Economic Association (Stern 2008).

THE STERN CLIMATE CHANGE MODEL

Figure 3 encapsulates Stern's message. It lists six basic propositions, shown by the headlines below as well as by the numbered items in Figure 3.

Scientists agree that climate change is real

A large majority of the world's scientists believe so, and that the main cause is caused by anthropogenic (human) activities. Doran and Zimmerman (2009) found that 97.4% of climatologists who are active publishers on climate change thought the main cause was anthropogenic, which is not really surprising. However, 88% of climatologists generally also thought so. This survey showed that the more scientists know about climate research, the higher is their response that anthropogenic factors are at play. But 77% of non-climatologist earth scientists also responded positively, and 58% of the general public according to a Gallup poll conducted at the time, though this leaves a significant 42% minority of deniers.[14]

Doran and Zimmerman concluded: "It seems that the debate on the authenticity of global warming and the role played by human activity is largely nonexistent among those who understand the nuances and scientific basis of long-term climate processes. The challenge, rather, appears to be how to effectively communicate this fact to policy makers and to a public that continues to mistakenly perceive debate among scientists." [15]

The greatest market failure ever

Economists refer to market failure when the main coordinating mechanism in a market – prices – sends the wrong signals. Prices of petrol or aluminum produced with dirty energy do not reflect the true cost to society of producing and using these goods. Without policy intervention too much of these goods will be produced and consumed. "By producing and consuming less of these products and more of others, we create economic gains that can make everyone better off. Markets with uncorrected failures lead to inefficiency and waste." (Stern 2009, p 11; page references in the following text are also from that source except when indicated.)

Market failures take many forms including lack of information, abuse of market power, and "externalities" where someone's action directly affects the prospects of others. Greenhouse gas emissions are clearly an externality and market failure because the actions of those producing them are paid for by everyone else.

Emissions differ fundamentally from congestion or local pollution

A company that dumps toxic waste into a river causes only local pollution, which can generally be dealt with locally. Greenhouse gas emissions are in a vastly different class because, as Figure 3 shows: it has *long-term* effects, the effects are *global*, the impact is

[14] Since grown into a majority according to opinion polls taken during 2009.

[15] Surveys in 2009 showed climate skeptics to be on the increase in the US.

highly *uncertain* but is potentially *huge*. Hence, these emissions constitute the greatest market failure the world has ever seen.

The risk for future generations is a crucial ethical issue

This is the centerpiece of Stern's economics of climate change. He insists that "the heart of economic analysis must be: the ethics of values both within and between generations; international collaboration; an appreciation of risk; and changes way beyond minor adjustments, or "marginal increments" in the jargon so beloved by economists." (pp 11-12)

Stern dismisses suggestions that ethics are outside the subject of economics, or that ethics are "revealed" by market behavior or outcomes. "Economists provide analyses that inform political processes and policy and moral judgements, and that can help to shape questions. Economic analysis can show the implications of different sets of values for decisions and show inconsistencies. Moreover, while markets can provide some limited information relevant to values, there is no way they can settle debates over which values should be used to guide decisions of this magnitude, collective responsibility and timescale." (p 12)

Ethics are at the center of the debate economists have had about the extent to which the future should be discounted compared with the present, in other words what value should be placed on their benefits compared to the present generation's. In terms of the Kashmiri proverb that we have borrowed the Earth from our descendants, the discount factor should be very low, that is, there should be little difference in the valuation of benefits of the present generation and the valuation of benefits of our grandchildren's generation. This consideration is complicated by the inequalities between rich and poor countries, and also by the possibility that our descendants will be richer than we are, and therefore may have less need for additional benefits.[16] But the general conclusion is still that ethics dictate a low discount rate to value the benefits of our own generation and the future.

We have already touched upon the likelihood that the future effects of climate change takes us out of the economist's comfort zone of dealing with marginal change in costs and benefits. The economics, as Stern puts it, are much more difficult and profound. (p 13)

Criteria for shaping policy

The economic policy criteria naturally include effectiveness in reducing emissions on the required scale. As we have seen, alternative policies are fiercely debated following the Copenhagen conference in December 2009, including the merits of a general carbon tax, whether a cap-and-trade scheme should apply generally or to power generation only, and whether policies should be directed toward individual carbon-intensive industries. The equity criterion is even more complex, because it has to recognize differences in incomes, both within and between nations, different access to technologies, and not least the impact of historical responsibility – notably that the developing world is being dealt a double whammy: poor countries are least responsible for the existing stock of greenhouse gases (though China, India, Brazil and Indonesia are catching up fast), but they are hit earliest and

[16] But Garnaut (2008) suggests that non-market factors such as environmental amenity may offset the impact of greater income and wealth. There is also an inherent flaw in the argument if world economic growth is at serious risk of becoming reversed in a warming world – the possibility demonstrated in Hoegh-Guldberg (2010b).

hardest by climate change. Stern notes: "The rich countries have major historical and other responsibilities, and must show leadership. Without it, global action must fail." (p 13)

The cost of inaction

Economists who have been involved in the analysis of climate change agree that the cost of tackling climate change now is moderate, and looked at in a long-term perspective makes no real difference in the future income flow of a country. The same economists, notably Stern and Garnaut, agree also that inaction can lead the world into a very difficult situation from which there may be no way back. Business-as-usual (BAU) scenarios are being increasingly seen as courting catastrophe. The three items in the bottom of Figure 3 summarize this.

GENUINE INTERDISCIPLINARY INFLUENCES

The approach to economic modeling offered by some scientists and touched upon in the section headed 'scientists offer to re-define economic theory' underestimates the quality and solidity of economic theory that has developed over the past two centuries or more. Economics is much more than predicting "bubbles and busts"; but econophysics may also be developing into an integral branch of *complexity theory*, as reported below.

Attempts by scientists to "help" economists in the belief that the "bubbles and busts" arena is the only central economic theory are very different from the real opportunities for the physical and behavioral sciences to develop and support one another, extending to "even … the arts and humanities" as 1969 Nobel Physics Prize winner Murray Gell-Mann observed in *The Quark and the Jaguar* in 1994.[17] Complexity theory is discussed below.

COMPLEXITY THEORY AND COMPLEXITY ECONOMICS

The role of a genuine interdisciplinary philosophy

Complexity theory has experienced a renaissance since the founding in 1984 of the Santa Fe Institute in New Mexico. Its influence may well be further absorbed into economic theory because of the perceived shortcomings of traditional economics in dealing with climate change and the economic and financial crisis. Complexity theory applied to economics is part of the attempted synthesis of a possible future economic paradigm outlined at the end of this background paper.

The theory originated in a scientific and engineering context during the immediate postwar years with the blossoming of the modern form of *cybernetics*, the interdisciplinary study of regulatory systems which formalized the notion of feedback and developed a wide range of applications from engineering, systems control, computer science, and biology, to philosophy and the organization of society.

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[17] An unpublished manuscript for the Australia Council for the Arts, *The Arts on the Edge of Chaos*, was to a large extent inspired by complexity theory (Letts 1995). The last chapter, "Culture and the Biosphere", refers to Gell-Mann's observation (1994) that we now have the capacity to destroy the biosphere, "whether deliberately or as a side effect of other activities." (p 213) Letts ponders what artists can contribute, noting: "Since biological evolution cannot cope, and since the problem originates with humanity, the only hope lies in a benign cultural evolution." These thoughts are remarkable in a 15-year old script, given that the threat to the planet's ecosystems has become greatly aggravated since 1995.

The work of British biologist and anthropologist Gregory Bateson across the fields of cybernetics (including information, communications and systems theory) was an important influence for many social and behavioral scientists who were first introduced to cybernetics by Bateson (Bale 1995). An important element of his work was his ecological philosophy, not at all common when he formulated it around 1970. "We are beginning to play with ideas of ecology, and although we immediately trivialize these ideas into commerce or politics, there is at least an impulse still in the human breast to unify and thereby sanctify the total natural world, of which we are." (Bateson 1979)

Complexity economics is the application of complexity science to the problems of economics. Complexity has become the last of the "four C's" of a new paradigm surfacing in the field of economics: cybernetics (1950s and '60s), catastrophe (1970s), chaos (1980s), and complexity (1980s to date), all governed by nonlinear dynamics and positive feedback processes. The new mode of economic thought queries the traditional neoclassical assumptions that imply that the economy is a closed system that eventually reaches an equilibrium. It views economies as open complex adaptive systems with *endogenous* evolution, including *endogenously generated technologies* to provide dynamic growth.[18]

In contrast, the neoclassical economic growth model pioneered by Solow (1956) treated the generator of growth, technology, as exogenous. Romer (1990) was the first to introduce a growth model in the neoclassical tradition with an endogenous technological driver. This, however, ignores Joseph Schumpeter, born in the same year as John Maynard Keynes (1883) and sometimes seen as his rival. As a young economist he wrote the German-language version of his *Theory of Economic Development* in 1911, which he revised in 1926 and which was translated into English in 1934. It divided economic processes into three different parts (as described by Elliott (1983) in his introduction to a new edition of Schumpeter's book):

1. In the absence of economic development, the competitive capitalist economy is reduced to a routine of maintaining the "circular flow" (*Kreislauf* in the German version) in a stationary general equilibrium. The economy would move along a stable equilibrium growth path, determined by small and gradual increases in the labor force, savings, and capital accumulation. There would be no entrepreneurs, only businesses reacting passively to changing market demand and cost structures. The "sovereign consumer" of classical and neoclassical economic theory would be king and queen.
2. The economic development comes from far within the economic system – it is an *endogenous* force and not merely a reaction to external stimuli. It occurs discontinuously, and it brings qualitative changes or "revolutions" which fundamentally displace old equilibria and create radically new conditions. It is accompanied by growth from sustained upward movements in national income, savings, and population. The development of the railroads in the 19th century and the automobile in the 20th emerged from the entrepreneurs in the commercial and industrial sectors of the economy, and not at all from the "sovereign consumer" of classical economics.

[18] http://en.wikipedia.org/wiki/Complexity_economics, accessed September 2009). See further Hoegh-Guldberg (2010d).

3. The third part is those economic processes that impede the undisturbed course of development.

A subsequent book by Schumpeter (*Capitalism, Socialism and Democracy*, 1943) contains a concise explanation of his economic view and his concept of *creative destruction*, which he called "the essential fact about capitalism. It is what capitalism consists in and what every capitalist concern has got to live in." See Addendum 2.

The main commentator on the "four C's" appears to be Rosser (1999). A few years previously, science journalist John Horgan had branded them a series of "failed fads", in opposition to the opinions within the Sante Fe Institute. Rosser takes a more positive view while conceding that it was still difficult when he wrote to identify a concrete and surprising discovery that had arisen due to the emergence of complexity analysis.

"Rather, complexity theory has shifted the perspective of many economists towards thinking that what was viewed as anomalous or unusual may actually be the usual and expected, especially in the realm of asset markets where the unusual seems increasingly commonplace! Indeed, there is a strain of common perspective that has been accumulating as the four C's of cybernetics, catastrophe, chaos and complexity emerged, which may now be reaching a critical mass in terms of influencing the thinking of economists more broadly." (p 187)

Catastrophe theory emerged during the 1970s. A catastrophe is a particular kind of discontinuity in a dynamic system. The discontinuities depend on distinct multiple equilibria and involve jumping from one to another as some control parameter gradually changes. Catastrophe theory generated an even greater multidisciplinary "fad" than did cybernetics, according to Rosser (p 172). Indeed, modeling discontinuities continues to be a major theme of more recent complexity models.

Chaos theory studies the behavior of dynamic systems that may be highly sensitive to initial conditions. Tiny differences in the starting state of the system can lead to enormous differences in the final state of the system even over fairly small timescales (popularly referred to as the "butterfly effect" – "a butterfly flapping its wings in Texas may cause a tornado in the Philippines"). Economists used chaos theory in the 1970s, but it became widely known through a best-selling book (Gleick 1988), which successfully explained the many aspects of the theory including esoteric matters such as the apparent ability of so-called fractals to reproduce themselves in ever-decreasing sizes in chaotic systems.

One term that became widely used in several disciplines in the 1990s was the "edge of chaos". The term was coined in 1990 by scientists associated with the Santa Fe Institute to deal with the highly mathematical properties of models called cellular automata.[19] However, the phrase quickly came to refer to a metaphor that some physical, biological, economic and social systems operate in a region between order and complete randomness or chaos, where the complexity is maximal. Figure 4 (redrawn from Beinhocker (1997)) shows "the edge of chaos" as the critical transition point between order and complete randomness or

[19] http://en.wikipedia.org/wiki/Cellular_automaton.

chaos, where the complexity reaches its maximum. The description below the graphic is Beinhocker's.

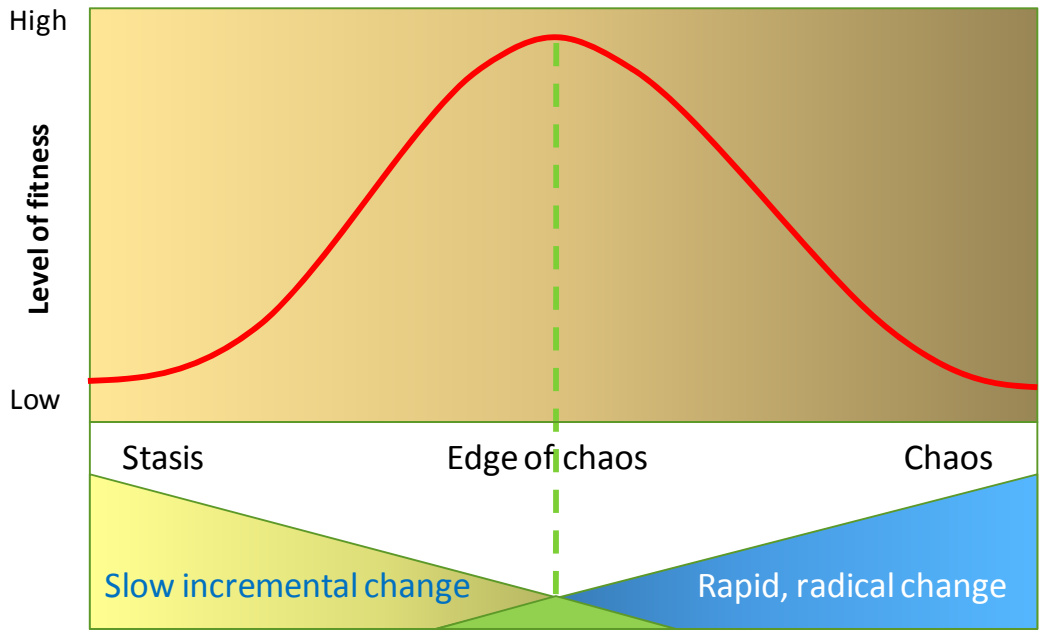

Figure 4: The edge of chaos. In a complex adaptive system, an agent that is resistant to change and not adaptable will have low fitness, and so, conversely, will an agent that is oversensitive to shifts in its environment and constantly making radical responses. But between these extremes of stasis and chaos lies a region – the edge of chaos – where fitness is maximized. Being at the edge of chaos means something more subtle than pursuing a moderate level of change. At the edge of chaos, one is simultaneously conservative and radical. Adapted with acknowledgments from Beinhocker (1997).

Whether or not the "three C's" described above became faddish through overuse or misuse is not our concern here. Many see complexity as a newer and higher stage of analysis, distinct from the previous "C's" of cybernetics, catastrophe, and chaos (Rosser 1999, p. 176). No tight definition exists, but speaking from the "Santa Fe perspective" W. Brian Arthur, Steven Durlauf and David Lane (1997) suggested that the following features identified in complexity economics present difficulties for the traditional mathematical models used in economics. Systems with these properties have come to be called *adaptive nonlinear networks*:

- **Dispersed interaction**: What happens in the economy is determined by the interaction of many dispersed, possibly heterogeneous, agents acting in parallel. The action of any given agent depends upon the anticipated actions of a limited number of other agents and on the aggregate state these agents co-create.
- **No global controller**: No global entity controls interactions. Instead, controls are provided by mechanisms of competition and coordination between agents. Economic actions are mediated by legal institutions, assigned roles, and shifting associations. Nor is there a universal competitor – a single agent that can exploit all opportunities in the economy.

- **Cross-cutting hierarchical organization**: The economy has many levels of organization and interaction. Units at any given level of behaviors, actions, strategies, products typically serve as `building blocks' for constructing units at the next higher level. The overall organization is more than hierarchical, with many sorts of interactions (associations, channels of communication) across levels.
- **Continual adaptation**: Behaviors, actions, strategies, and products are revised continually as the individual agents accumulate experience – the system constantly adapts.
- **Perpetual novelty**: Niches are continually created by new markets, new technologies, new behaviors, new institutions. The very act of filling a niche may provide new niches. The result is ongoing, perpetual novelty.
- **Out-of-equilibrium dynamics:** Because new niches, new potentials, new possibilities are continually created, the economy operates far from any optimum or global equilibrium. Improvements are always possible and indeed occur regularly.

Inspiration from polymaths

The multidisciplinary quality applies not only to the general approach to complexity but also to many of its practitioners who are true polymaths. Their broad orientation has helped substantially to make complexity a genuine influence across a wide range of disciplines.

Among the persons active in the Santa Fe Institute, *Murray Gell-Mann* is a physicist specializing in elementary particles (he is famous for finding and naming the quark as a pivotal building block in his hierarchy of subatomic particles which earned him the Nobel Prize in 1969), but according to his Nobel Prize biography,[20] "Gell-Mann's interests extend to historical linguistics, archeology, natural history, the psychology of creative thinking, and other subjects connected with biological and cultural evolution and with learning. Much of his recent research at the Santa Fe Institute has focused on the theory of complex adaptive systems, which brings many of those topics together."

William Brian Arthur also has broad professional qualifications. His undergraduate degree was in electrical engineering, followed by two M.A.s in operations research and mathematics, respectively. He obtained his Ph.D. in operations research in the same year (1973) that he took an M.A. in economics. At 37 (1982) he became the youngest endowed professor at Stanford University, in economics and population studies. Arthur has had great influence on the development of complexity economics, and complexity theory generally, at the Santa Fe Institute with which he remains associated as an External Professor, as well as being a Visiting Researcher at the Palo Alto Research Center for commercial innovation (PARC). He was joint winner of the Schumpeter Prize in Economics in 1990, when the theme for the prize was evolutionary economics. In 2009 he was joint winner of the inaugural $110,000 Lagrange Prize in Complexity Science. [21]

[20] http://nobelprize.org/nobel_prizes/physics/laureates/1969/gell-mann-bio.html.

[21] Arthur in 2009 wrote an important book on the evolutional nature of technology, which forms the basis for the discussion in Hoegh-Guldberg (2010d). Apart from Darwin (12), Schumpeter has the largest number of index references (9).

Herbert A. Simon, who was awarded the Nobel Prize in Economics in 1978 for his pioneering research into the decision-making process within economic organizations, was perhaps the greatest polymath of them all – an American economist and psychologist (with a Ph.D. in political science) whose research ranged across the fields of cognitive psychology, computer science, public administration, economics, management, philosophy of science and sociology. He was the Richard King Mellon Professor of Computer Science and Psychology at Carnegie Mellon University in Pittsburgh, Pennsylvania, where he taught for 52 years.

Simon was among the founding fathers of artificial Intelligence, information processing, decision-making, problem-solving, attention economics, organization theory, complex systems, and computer simulation of scientific discovery. He was the first to analyze the architecture of complexity (Simon 1962). As well as receiving the highest honor possible in economics, he was the recipient of the American Psychological Association's Award for Outstanding Lifetime Contributions to Psychology in 1993, and the prestigious A. M. Turing Award for his work in computer science (1975). [22]

Parallels in traditional science and traditional economics

Science has a traditional orientation that has proven extraordinarily successful. Scientists have historically taken a top-down, reductionist approach in which the universe is broken into ever-smaller pieces in search of ultimate laws, from the level of galaxies to subatomic particles. Many of the hardest problems in nature, however, are "complex systems" that have collective or emergent characteristics that are better understood through a bottom-up, holistic approach (Beinhocker 2006). Ecology and climate science are on top of that list.

Economics faces a different dilemma, due to its focus on abstract rather than observable entities. The traditional approach has dominated economic theory for a century and remains the frame of reference in most university textbooks, and for the media, business and government. Though economists are more prone than scientists to build their theory on assumptions such as "rational economic man" and other artificial concepts of neoclassical equilibrium economics, it would be monumentally wrong to reject the discipline. No responsible economist would contemplate such a step. Its main weakness is parallel to the reductionist approach in science, and can be supplemented in similar fashion through holistic, bottom-up approaches. The economics as well as the science of climate change exemplifies this. Brian Arthur remarks: "The result, complexity economics, is not an adjunct to standard economic theory, but theory at a more general, out-of-equilibrium level." (Arthur 1990, p 107) [23]

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[22] http://en.wikipedia.org/wiki/Herbert_Simon.

[23] This article, in *Scientific American*, is concise but not the ultimate paper Arthur wrote in 1989, in which he developed the concepts of positive feedback and increasing returns. In an interview with Jaworski et al. (1999) he said that "if there was a moment of epiphany, it was in June 1979 when I read a little essay that [Russian/Belgian physical chemist and Nobel Laureate Igor] Prigogine had written. I forget what he called it, … but it was about positive feedback, and instantaneously I realized I had something that was important in economics. All I needed to do was figure out how positive feedbacks worked in economics, and it took another ten years to do that. But suddenly, within about two or three weeks, everything in economics fell into place for me. It was a period of very, very intense intellectual excitement." The paper was eventually published in *The Economic Journal* (Arthur 1989).

The Santa Fe Institute

The Institute describes itself as "devoted to creating a new kind of scientific research community, one emphasizing multi-disciplinary collaboration in pursuit of understanding the common themes that arise in natural, artificial, and social systems. .. The Santa Fe Institute is a private, not-for-profit, independent research and education center founded in 1984, for multidisciplinary collaborations in the physical, biological, computational, and social sciences. Understanding of complex adaptive systems is critical to addressing key environmental, technological, biological, economic, and political challenges. Renowned scientists and researchers come to Santa Fe Institute from universities, government agencies, research institutes, and private industry to collaborate in attempts to uncover the mechanisms that underlie the deep simplicity present in our complex world.[24]

The last part of the statement is a reflection on co-founder Murray Gell-Mann's *Quark and the Jaguar* (1994), which sets forth his "views on an emerging synthesis at the cutting edge of inquiry into the character of the world around us – the study of the simple and the complex." (p ix)

Beinhocker (2006) writes: "The group had set itself the modest ambition of fundamentally changing the way in which scientific research is conducted." The view was that the reductionist approach to scientific research had to be urgently supplemented with the bottom-up, holistic perspective mentioned in the previous section.

Economics entered soon after the foundation of the Santa Fe Institute. As Beinhocker (2006) tells the story, John Reed at 45 in 1984 had just been elected chairman and CEO of Citicorp, a banking company that had recently been through a major trauma. Like other banks, it had lent aggressively to Latin American and other governments in the 1970s. This had been regarded as "safe banking" because governments did not default on their debts. But Mexico did so in 1982.

Reed could not understand why the best brains at Citicorp and the other major banks so badly misjudged the risks. He consulted leading economists from academia, Wall Street and the government, but they apparently had few insights to add about the crisis.

Having got in contact with the Santa Fe scientists, Citicorp in 1987 agreed to fund a cross-disciplinary workshop with a group of 10 leading economists invited by famed general equilibrium theorist and Nobel Prize winner Kenneth Arrow. They included Larry Summers who went on to become Treasury Secretary in the Clinton administration and more recently Director of President Obama's National Economic Council. The line-up of 10 scientists who also participated was no less impressive.

The meeting resulted in the founding, in 1988, of the Economics Program at the Santa Fe Institute, the Institute's first resident research program. Most important for the subsequent development, W. Brian Arthur, who remains associated with the Institute, was another member of the group of 10 economists. He has probably done more than any other individual to develop complexity economics.

[24] http://www.santafe.edu/.

His research into positive feedback in dynamic economic models (Arthur 1989, 1990) shows an important way forward. Conventional economics, he says, is based on diminishing returns, which means that economic actions eventually engender a negative feedback that leads to a predictable equilibrium for prices and market shares. Negative feedback tends to stabilize the economy because any major changes will be offset by the very reactions they generate. But this may not tell the real story.

"In many parts of the economy, stabilizing forces appear not to operate. Instead, positive feedback magnifies the effect of small economic shifts; the economic models that describe such effects differ vastly from the conventional ones. Diminishing returns imply a single equilibrium point for the economy, but positive feedback – increasing returns – make for multiple equilibrium points. There is no guarantee that the particular economic outcome selected from among the many alternatives will be the "best" one. Furthermore, once chance economic forces select a particular path, it may become locked in regardless of the advantages of other paths."

This view of positive feedbacks is strongly connected with technological change. Although there is no guarantee that the best technology wins out,[25] "technologies typically improve as more people adopt particular technology, the more it improves, and the more incentive there is for further adoption." He concludes: "With the acceptance of positive feedbacks, economists' theories are beginning to portray the economy not as simple but complex, not as deterministic, predictable and mechanistic, but instead as process-dependent, organic and always evolving." (Arthur 1990)

Expanding econophysics?

This question needs to be addressed – although with some reservations – because it is being quite vigorously pursued, and has links to complexity theory and the Santa Fe Institute. Econophysics is also associated with the dominant mathematical school of neoclassical economics, including its genesis in works such as Samuelson's *Foundations of Economic Analysis* from 1947 which the author stated was inspired by physical science (Samuelson 1998). The pendulum appears to have swung toward greater affinity with biology and ecology than with physics. This is discussed further in the beginning of the next main section: "What might this mean for economics in the future?"

The journal *Complexity* in 2008 devoted a full issue to the subject of econophysics, which is related to complexity economics though the latter term implies a broader scientific input. It was edited by the well-known mathematical economist Martin Shubik (one of the fathers of game theory back in the 1950s) and physicist Eric Smith. Both are currently associated with the Santa Fe Institute, as were several of the contributors to the issue (physicist Doyne Farmer and economist John Geanakoplos writing about the future of financial markets , and physicist Fabrizio Lillo).

[25] One very large example of conflicting technologies from which the best outcome probably failed to eventuate, even ignoring the resulting climate change, would be the battle between electric and gas-driven cars in the early part of the 20th century described by Edwin Black in *Internal Combustion* (2006).

Lillo (2009) puts the rise of econophysics in the context of the more general interest of physicists and other scientists towards complex systems. He thinks there are at least "three topics in which econophysics could give interesting insights and therefore are more likely to develop. First, up to now econophysics has been strongly biased toward finance. A progressive shift of econophysics toward other branches of economics different from finance is certainly desirable. Macroeconomics, for example, is a field where the interaction between physicists and economists has been quite sporadic." (p 53) It may be argued that Paul Samuelson's seminal treatise in 1947 helped trigger the dominance of mathematical economics, related to principles originating in physics.

Secondly, however, Lillo feels econophysics has made a useful contribution in the area of finance and should be encouraged to continue to do so. "As for the third topic, the recent availability of large data-sets on the behavior of individuals in different socioeconomic systems will open up the development of a new type of agent based modeling. In this modeling, the output from empirical analyses on agent's behavior will be used as an input for agent based modeling, which in turn can give insight on the empirical facts (and the type of data) to look at. This synergic interaction between modeling and empirical analysis … is in my opinion the most challenging playground for the dialogue between physics and economics." (p 53)

Farmer and Geanakoplos (2009) set out "to convince the skeptics that equilibrium models can be useful, but also to make traditional economists more aware of the limitations of equilibrium models." (p 11) Equilibrium theory "is an elegant attempt to find a parsimonious model of human behavior in economic settings. It can be criticized, though, as a quick and dirty method, a heroic attempt to simplify a complex problem. Now that we have begun to understand its limitations, we must begin the hard work of laying new foundations that can potentially go beyond it." (p 34)

The focus in the Farmer and Geanakoplos paper is the general equilibrium theory of Arrow and Debreu (1954), based on the assumptions of perfect competition (price taking); that agents always optimize their utility within the limitations of the model; on market clearing to maintain equilibrium at all times; and on rational expectations based on perfect information. The model showed that there "always is an equilibrium, no matter what the endowments and technologies and utilities, provided that each utility displays diminishing marginal utility of consumption and each technology displays diminishing marginal product." (p 13)

The subjects in these papers remain biased towards financial markets. This is in the very title of the Farmer and Geanakoplos paper, as well as Lillo (2009), which focuses on the efficient market hypothesis, a "cornerstone in economics" stating that a market in which prices always fully reflect available information is "efficient**".** Shubik and Smith (2009) conclude their review of the papers in the special issue of *Complexity* (p 10):

"The perspective from these reviews is that much progress has been made, especially in data-rich applications in domains such as finance. These are not merely gains in method; natural-science modes of data interpretation and model validation are impacting core concepts about market function. At the same time, many questions of fundamental interest to economists are not reflected in this work, and whether they fit within the methodology of

natural as well as social science remains an open question. At least, for the present, the answer is not clearly "no." "

One interesting parallel with what has been previously noted in climate models (the fat-tail analysis by Weitzman (2009)) is the occurrence of heavy-tailed distributions in price series, income and wealth distributions, and other social phenomena. "These "excesses" of rare

Aspect	Complexity Economics	Traditional Economics
Dynamic	Open, dynamic, non-linear systems, far from equilibrium	Closed, static, linear systems in equilibrium
Agents	Modelled individually; use inductive rules of thumb to make decisions; have incomplete information; are subject to errors and biases; learn to adapt over time; heterogeneous agents	Modelled collectively; use complex deductive calculations to make decisions; have complete information; make no errors and have no biases; have no need for learning or adaptation (are already perfect), mostly homogeneous agents
Networks	Explicitly model bilateral interactions between individual agents; networks of relationships change over time	Assume agents only interact indirectly through market mechanisms (e.g. auctions)
Emergence	No distinction between micro/macro economics; macro patterns are emergent result of micro level behaviours and interactions.	Micro-and macroeconomics remain separate disciplines
Evolution	The evolutionary process of differentiation, selection and amplification provides the system with novelty and is responsible for its growth in order and complexity	No mechanism for endogenously creating novelty, or growth in order and complexity
Technology	Technology fluid, endogenous to the system	Technology as given or selected on economic basis
Preferences	Formulation of preferences becomes central; individuals not necessarily selfish	Preferences given; Individuals selfish
Origins from physical sciences	Based on biology (structure, pattern, self-organized, life cycle)	Based on 19th-century physics (equilibrium, stability, deterministic dynamics)
Elements	Patterns and possibilities	Price and quantity

Source: Wikipedia (http://en.wikipedia.org/wiki/Complexity_economics, accessed 4 September 2009).

Figure 5 illustrates the differences between the complexity perspective and classical economics. Eric Beinhocker (2006) proposed five concepts that distinguish complexity economics from traditional economics. The first five categories are Beinhocker's synthesis, the last four are from W. Brian Arthur as reprinted in Colander (2000).

events have pointed, perhaps more than any other quantity, to inadequacies of equilibrium theories, and have provided much of the support for ideas drawn from natural sciences to study them. **"** This parallel with climate-change economics would be worth pursuing.

Traditional versus complexity economics

Figure 5 is reproduced from Wikipedia's description of complexity economics; the anonymous contributor is gratefully acknowledged. The top five items were derived from Beinhocker (2006), the bottom four from W. Brian Arthur's work. The items speak for themselves but it is useful to read them in conjunction with the previous six-point description of adaptive nonlinear networks (Arthur et al. 1997).

Constructively dissident economic voices are not a new phenomenon

The time may have been right for complexity theory to start influencing economics in the 1990s, but highly reputable mainstream economists have tried for decades to challenge the assumptions of the "neoclassical paradigm with its fundamental notions of rational, optimizing consumers making choices in a world of finite resources." (Beinhocker 2006)

Within a limited space, the evidence presented here cannot be encyclopedic. We can only deal with relatively recent examples of challenges to neoclassical economics. The following case is considered representative in addition to Brian Arthur's direct influence on complexity economics and Herbert Simon's work on 'satisficing' and other modifications – not to mention the identification of animal spirits by Keynes himself, and Schumpeter's insights which includes the basic role of technology as an endogenous economic driver. We add that Leijonhufvud's paper quoted below shows him to be well aware of the then emerging complexity economics; indeed, he was a contributor to Arthur et al. (1997), which contains the proceedings of a Santa Fe Institute workshop in 1996.

Back in 1950, UCLA economist Armen A. Alchian wrote what became a classical paper titled *Uncertainty, Evolution, and Economic Theory.* He stated in his introduction (Alchian 1950, p 211):

"The suggested approach embodies the principles of biological evolution and natural selection by interpreting the economic system as an adoptive mechanism which chooses among exploratory actions generated by the adaptive pursuit of "success" or "profits." The resulting analysis is applicable to actions usually regarded as aberrations from standard economic behavior as well as to behavior covered by the customary analysis. This wider applicability and the removal of the unrealistic postulates of accurate anticipations and fixed states of knowledge have provided motivation for the study."

Forty-odd years later, a younger UCLA colleague, Axel Leijonhufvud, envisaged a "not-too-rational macroeconomics" inspired by Alchian (Leijonhufvud 1993). He quoted a friend saying that "practical men of affairs, if they know anything about economics, often distrust it because it seems to describe the behavior of *incredibly smart people in unbelievably simple situations.*" He noted, however, that "standard economic theory is useful in a myriad ways, despite its unrealistic assumptions about people's cognitive capabilities, because the interaction of ordinary people in markets very often does produce the incredibly smart result. When it does, it can be a convenient short-cut to model the social interaction process

as if it was planned (and policed) by a representative agent or social planner possessed of rather superhuman abilities." (p 2)

So the rationalist model may work despite the limited knowledge of its agents, but it is by no means certain as Leijonhufvud duly notes in his conclusion (quoted below).

Alchian advocated a method "very much at variance with the one that dominates macrotheory today, a method ... which treats the decisions and criteria dictated by the economic system as more important than those made by the individuals in it." Leijonhufvud notes that efficiency, in the Alchian model, "stems less from the ex ante rational planning of typical economic agents than from the ex post elimination through competition of ill-adapted modes of behavior. We might start, then, by asking how *believably simple people cope with incredibly complex situations*. If we knew a bit about that, we could then go on to study the conditions under which market interaction will and will not configure the complex system into that incredibly smart allocational pattern. Because, of course, social interaction does not always produce the perfectly rational result. Sometimes, as James Tobin once said, "the invisible hand is nowhere to be seen." Ordinary people also interact to produce booms and busts in real estate, credit crunches and bank panics, great depressions and hyperinflations – and much other misery besides." (p 2)

Leijonhufvud concludes (p 12):

"To understand what is actually going on, I strongly believe, one must abandon this entire mode of theory construction and rethink the matter from Alchian's evolutionary perspective. Here believably simple people face incredible complications and, finding themselves unable to precalculate the consequences, give up trading in most future markets. New externalities appear where price-interaction has withered away. As coordinating mechanisms disappear, imperfect decision-makers no longer face the same Darwinian pressures to adapt. Potential gains from trade are left unexploited. Various inefficient practices survive. Resources fail to find their highest valued uses. The difference between the two approaches matters. The rationally expectant optimizers of today's standard theory do not need market interaction to teach them how to attain the efficient social outcome. Alchian's imperfect decision-makers do. But an Alchian market-process is not an aggregate of mutually consistent optimal decisions. So, it cannot be modeled in the standard way. But I believe we can do it in the computable way."

The last remark is a reminder that neoclassical economics was formulated when computers were in their infancy rather than in 1993 when Leijonhufvud felt encouraged to believe in computer power. The macro-econometric models of the immediate postwar years involved less than 10 stochastic[26] equations. The Klein interwar model of the United States economy over the period 1921-41, published in 1950, involved three stochastic and three non-stochastic equations in six endogenous and four exogenous variables. A celebrated model of the U.S. economy from 1929-41 and 1946-52, Klein-Goldberger from 1955, involved 15 stochastic and five non-stochastic equations in 20 endogenous and 14 exogenous variables. (Intriligator 1983, p 205)

[26] Random variables were included, typically as additive stochastic disturbance terms, to account for omission of relevant variables, incorrect model specifications, and errors of measurement (Intriligator 1983, p 187).

BEHAVIORAL ECONOMICS AND THE POTENTIAL CONTRIBUTION FROM PSYCHOLOGY

Within the behavioral sciences, there is a natural affinity between economics and psychology, which has recently returned to prominence through publications like Akerlof and Shiller's *Animal Spirits*, and also through a recent report by an American Psychological Association task force on psychology's potential contribution to combating climate change.

Behavioral economics is related to neuroeconomics, indicating that some branches of economics are reaching out to the biological and medical sciences. Money illusion, for example, has been shown to be associated with a specific site in the pre-frontal cortex of the brain (Stix 2009).

The founder of modern behavioral economics, Daniel Kahneman, noted in his Nobel Prize address in 2002 that his paradigm differed from the traditional version (Kahneman 2003): "Theories in behavioral economics have generally retained the basic architecture of the rational model, adding assumptions about cognitive limitations designed to account for specific anomalies. For example, the agent may be rational except for discounting hyperbolically, evaluating outcomes as changes, or a tendency to jump to conclusions.

The model of the agent that has been presented here has a different architecture, which may be more difficult to translate into the theoretical language of economics. The central characteristic of agents is not that they reason poorly but that they often act intuitively. And the behavior of these agents is not guided by what they are able to compute, but by what they happen to see at a given moment."

This seems to fit the animal spirits model well. However, despite Kahneman's undoubted influence in both disciplines it is difficult to find positive links where psychological insights are of great benefit for macroeconomic analysis, specifically in the area of climate change.[27] The American Psychological Association task force report (Swim et al. 2009) addresses how psychologists can assist in limiting climate change:

"Climate change now occurring globally is driven by a variety of human actions. The proximate causes include burning fossil fuels, clearing forests, raising cattle, and other actions that release greenhouses or change the reflectivity of Earth's surface. These actions in turn result from other human activities, including government policies, population increases and migrations, economic development activities, and the behavior of individuals and households as consumers, members of organizations, and citizens – and in turn from underlying human attitudes, predispositions, social and economic structures, and beliefs.

[27] Behavioral economics seems to have taken on a better hold at the microeconomic level (Lovallo and Sibony 2010). "Once heretical, behavioral economics is now mainstream. Money managers employ its insights about the limits of rationality in understanding investor behavior and exploiting stock-pricing anomalies. Policy makers use behavioral principles to boost participation in retirement-savings plans. Marketers now understand why some promotions entice consumers and others don't." The authors present a typology to identify cognitive bias such as excessive optimism, overconfidence, competitive neglect, and interest biases such as misaligned individual incentives and disagreements (often unspoken) about the objectives pursued by the organization and the tradeoffs between them. Such biases at corporate management level would have their aggregate counterparts, fitting into the broad realm of animal spirits.

Psychological science would seem indispensible for understanding and finding ways to change at least some of these human behaviors. Nevertheless, psychologists have rarely been consulted by climate policy decision makers." (p 136)

They don't seem to have peddled their services much either. The APA report comes across in a somewhat abstract way without an apparent attempt to define how the contribution of psychology could be integrated with other disciplines, notably economics. Delving into the report, Aldhous (2009) reviews some "tricks that could be deployed by companies or organizations to encourage climate-friendly behavior." The following may represent some of the more promising avenues:

- Most people want to be good neighbors and fit in with the crowd, which psychologists exploit to encourage environmentally friendly behavior.
- Some domestic appliances and cars display energy usage and savings, which helps provide incentives for using less.
- Some psychological research aims at persuading people to act on climate change even though the benefit won't be felt for decades. For instance, schemes that give people an upfront cash payment for insulating their home will work better than those promising long-term savings, even if the people receiving cash end up paying a little more in the long run.
- People are social animals who like to interact with others and take inspiration from their actions. Psychologists are working out how to exploit this to spread behaviors that will help limit climate change. The lead author of the APA report, Janet Swim, says, "My sense is that social networks are going to be important."

Social psychologist Mark van Vugt (2009) reports on interdisciplinary research into how people across cultures interact with nature and how it affects their wellbeing. This could lead to the triumph – rather than the tragedy – of the commons. Famous Harvard biologist Edward O. Wilson coined the term *biophilia* (in a book of the same name published in 1984) to describe the idea that we have a basic need to enjoy and affiliate with nature. Van Vugt comments: "If it turns out to be hard-wired, the biophilia could be another strong motivator in persuading people to protect the environment." (p 41) There are echoes here of Bateson's 40-year-old ecological philosophy.

The APA report and van Vugt's observations suggest that one important potential contribution from psychologists is the role of altruistic behavior. Graeme Taylor's observation that women's rights, peace, social justice, and the environment represent four growing areas of societal change suggests that there are countervailing forces to economic selfishness – businesses too are demonstrating large-scale altruistic behavior Hoegh-Guldberg (2010a). A cynic might dismiss this, and the role of ethics in the Stern and Garnaut reports on climate change, and the Millennium Goals to eliminate poverty, as survival mechanisms. It would be vastly preferable to contemplate how these positive psychological behaviors might be mobilized in the fight against climate change.

To help achieve this, the bond between the sister disciplines of psychology and economics needs to be nurtured and developed, especially as far as the direct contribution of mainstream psychology is concerned. Kahneman's and Simon's influence has been through

direct input into economic thinking from their dual academic backgrounds in economics and psychology, but direct cooperation between the two disciplines on specific issues such as climate change still seems to be some distance off.

The APA report notes (Swim et al. 2009, p 138): "Policy makers are increasingly coming to recognize that the dominant physical-technical-economic model of energy use is incomplete and are turning to behavioral scientists for better conceptual models and for advice on how to implement them so as to make policies and programs more effective." While it is not yet very visible, the APA's initiative in putting a task force together specifically on climate change is laudable, and may lead to more advanced analysis of what psychologists can contribute on their own and in cooperation with economists.

WHAT MIGHT THIS MEAN FOR ECONOMICS IN THE FUTURE?

ANIMAL SPIRITS AND MARKET FAILURES

The analysis of "animal spirits" revived by Akerlof and Shiller (2009) is an important contribution which deals directly with the sources of the global economic and financial crisis precipitated by the Lehman Brothers failure in September 2008. It lists the animal spirits responsible as *confidence*, *fairness*, *corruption and bad faith*, *money illusion*, and *stories*. They cause the business cycle to fluctuate more violently than if people had acted "rationally" at all times – the assumption which appears to encapsulate the major weakness of conventional economic theory.

Animal spirits also play a prominent part in the research into the need for an uncertainty principle in economics (Ball 2010). The current "taxonomy of uncertainty" at the MIT Sloan School of Management under Andrew Lo is important in this respect, because it helps in determining how far economic models are useful and where they fail (Lo and Mueller 2010, Brennan and Lo 2009). Lo and his colleagues hope it will be possible to extend the analysis to incorporate the "irrational" animal spirits, given greater knowledge and greater computational power. They also point to the need for economics to reduce its need for mathematical models inspired by physics, in favor of inspirations from biology (including evolutionary biology), ecology, and meteorology.

The uncertainty principle is of obvious relevance to climate change. In this respect, the alleged failure of economists to recognize "fat-tailed" probability distributions – giving more weight to extreme values than the normal Gaussian distribution – is highly important (Ball 2010). While the MIT work focuses on commodity prices, Weitzman (2009) and others have shown that the uncertainty and risk associated with accelerating climate change has similar characteristics.

The next question, which is related to the previous paragraph, is: are "animal spirits" also involved in the emerging economics of climate change and its causes? The two main books under review here don't provide explicit guidance. Akerlof and Shiller never mention Stern's central concept of market failure, and Stern makes no reference to Keynesian animal spirits. The answer, however, is yes.

Market failure is failure of the price mechanism. Manufacturers of products dependent on fossil fuels for energy or raw materials have paid little or nothing for polluting the atmosphere and oceans. As a result, major renewable energy technologies were delayed for decades and without corrective action remain generally uncompetitive with fossil fuels.

This situation has almost certainly eventuated as a result of a long history of animal spirit activities. In his book *Internal Combustion*, Edwin Black (2006) tells the story of how America in the early 20th century seemed well on the path towards electric motor vehicles, with Thomas Edison and Henry Ford collaborating to mass-produce electric cars powered by personal backyard energy stations. But petroleum interests effectively set the path that favored the internal combustion engine, with General Motors as a key player. The story invokes plenty of animal spirits and Black himself says that the book is about greed and deception. The resulting market failure appears to have been caused mainly by sheer abuse of power, plus the unfortunate fact that Edison's laboratory complex was destroyed by fire at the crucial time which seems to have finally set the internal combustion engine on the road to victory. The impact almost a century later needs no elaboration.

For market failure to happen, especially on the scale causing climate change, animal spirits remain a prominent part of the explanation. Ethics and fairness go hand in hand, for example, and Stern explicitly refutes the neoclassical macroeconomic assertion that ethics can be "revealed" through the market mechanism (see Figure 3). Fairness – one of the animal spirits – towards future generations and between rich and poor nations is among Stern's foremost concerns. Fairness was evidently in short supply when electric and gasoline power struggled for supremacy a century ago.

It is suggested in the introduction to this background paper that the current economic crisis may cause a sea change – it may lead to adjustments in the respective roles of business, government, and the society at large. On the other hand, it may not. The climate threat could provide an even more powerful motivation, or it may fail to break through the institutionalized pattern of inertia and vested interests. This uncertainty explains the decision to incorporate economic policy assumptions as a factor in our four scenarios.

COMPLEXITY AND THE ROLE OF OTHER DISCIPLINES

Adding complexity theory and complexity economics to the current economic paradigm is a natural extension. It offers new perspectives which should help policy-makers respond to the climate reality by analyzing more efficiently the broad range of emerging complexities, from China's "cleantech" initiatives and their implications for global technological and trade developments, to the intricacies of new taxation and other public policy schemes and international negotiations aimed at climate change protection.

Although neither Akerlof and Shiller, nor Stern, move irrevocably beyond the prevailing economic theory, both ascribe a major role to other disciplines. Akerlof and Shiller's invocation of psychology to explain the animal spirits dates back to Keynes's *General Theory*, and their book is a timely reminder for those immersed in neoclassical economics and the financial and economic policies that flow from that philosophy.

Stern's climate-change model runs more deeply into the top-down versus bottom-up dilemma that confronts economics. Top-down economics rules the standard economic

policies and general understanding of economic and fiscal matters. But the issue of climate change can only be captured if it is also tackled from the bottom up, and that approach gains precedence.[28] It is associated with the fate of ecosystems and biodiversity in the broadest sense; with the depletion of natural resources that have taken millions of years to build up; and on the human and institutional level with resistance and vested interests defending "business-as-usual", and ultimately with issues of national and international poverty and security, and risks of warfare and aggravated domestic social unrest.

An important contrast with traditional economics, apart from defining the role of technology as a truly dynamic endogenous driver of growth and development, is the recognition that complexity economics produces indeterminate results. Edwin Black's description of the struggle between electric and gasoline-powered cars a century ago exemplifies how the fate of alternative technologies can be sealed by random events (the Edison fire) and power struggles (GM and others versus Edison and Ford).

Complexity theory will continue developing, and the most important impact of this may be further progress of collaborative efforts between the physical and behavioral sciences. If so, this could have a profound impact on the economic theory and policy of the future, which may show up first in relation to climate change. However, the recognition of what is being almost jocularly referred to as animal spirits is also important: its first impact might be through renewed collaboration between economists, psychologists and other social scientists in the search for a more communally sensitive top-down approach.

LESSONS FOR CLIMATE CHANGE POLICY FROM RECENT EVENTS

This final section reflects events of 2009-10, including the impact of the global economic crisis and resurgent climate change denial which has been instrumental in bringing about a failure to pass comprehensive emissions trading schemes (ETS) in the USA and other countries including Australia. From being touted as the "ultimate" solution, these schemes through labyrinthine negotiating processes in 2009 were perhaps fatally weakened by compromises and exceptions. This has led many people to say that other instruments such as a straightforward carbon tax or differential treatment of individual industries would be more effective if the world is to proceed toward a non-fossil fuel economy.

These events give an additional climate-policy perspective to the role of economics in complex times, which may resonate in future years. The economic crisis was at least partly responsible for the relative failure of the climate change conference in Copenhagen, Denmark, in December 2009 (COP-15). President Obama was forced to change his political priorities from the very beginning of his administration, and conservative forces gained politically in the process. Other countries had similar experiences, again including Australia with a radicalized conservative opposition.

[28] The same applies in principle to health, education, culture, and other social policies which affect the societal fabric and sense of fairness and equity within and among nations.

THE COPENHAGEN ACCORD

The Copenhagen Accord[29] was drawn up on the last day of the COP-15 conference by only five participating countries (the United States, China, India, Brazil, and South Africa). It is not legally binding and limited in scope, setting no real targets and no path towards a strong succession agreement to the Kyoto Protocol, which runs out in 2012. This puts the onus on the next UNFCCC conference (COP-16) in Cancún, Mexico, in November-December 2010. COP-16 is preceded by meetings in Bonn, Germany, in April and June, involving the developed Annex I countries and the UNFCCC Subsidiary Bodies, respectively.

Notwithstanding its failure to produce a legally binding framework and a forward path, the Copenhagen Accord gave rise to some noteworthy new thoughts or concepts (Heffernan 2010):

- For the first time in an official declaration, it recognizes the need to limit the increase in global temperature to 2^{O}C above pre-industrial levels.
- It commits the developed countries to provide a total of $30 billion between 2010 and 2012 to help developing nations adapt to climate change, rising to $100 billion per annum by 2020, to be administered by a green climate fund.
- It includes aspirational targets for greenhouse gas emissions. Over half of the 192 countries participating in COP-15 (107) had responded by March, when the last two major countries to sign up, India and China, announced their intention to participate. This added considerable credibility to the approach, though the targets fall short of absolute commitments. [30]

Olive Heffernan (2010), editor of the *Nature Climate Change Report*, presented the comments of six international experts on "the road from Copenhagen." These views are encapsulated below:

- Mike Hulme of the University of East Anglia, UK, has formed the view that we need to set near-term targets that are pragmatic, technology-based, and achievable based on credible social, technical and economic analysis, "not aspirational targets driven by IPCC science." "I wouldn't mind too much if the climate bill doesn't get through the Senate if it forces other types of thinking."
- Jonathan Lash of the World Resources Institute, Washington, DC, saw a binding legal agreement, delivered in Mexico, as the ultimate goal. There will be key indicators of progress along the way. The first was the January 31 deadline by which countries were asked to submit their intentions to reduce greenhouse gases (reaching 109 responses by March as noted above, and over 120 by the end of June). Other indicators will be the content of China's 12th Five-Year Plan, 2011-15, and the passage of US climate legislation (this has become a problematical prospect in view of the current political situation and the coming mid-term elections in November).

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[29] Reproduced in full at http://unfccc.int/resource/docs/2009/cop15/eng/l07.pdf.

[30] The count at the end of June 2010 was "more than 120", of which over 75 had set targets, according to Connie Hedegaard, the EU's climate action commissioner and former Danish climate change and energy minister (http://www.euractiv.com/en/climate-environment/hedegaard-tax-what-you-burn-not-what-you-earn-interview-495623).

- David Victor, Stanford University: COP-15 provided no clear milestones or compass for the next round of diplomatic efforts. COP-16 in Mexico probably won't deliver a clear outcome. The Kyoto Protocol expires in 2012, which may send governments scrambling to secure instruments such as the Clean Development Mechanism, already undermined by the inconclusive outcome in Copenhagen. It is essential to find an acceptable path for the countries that really matter, notably the China and the US. The underlying cause of the failure is a basic lack of public interest in addressing the problem. "So far, very few people are willing to pay substantial amounts of money to avoid uncertain and distant global warming, and government policy reflects that reality."

- Hans Joachim Schellnhuber of the Potsdam Institute for Climate Research, Germany, called COP-15 a "landmark event": (1) The global policy-making elite assembled there confirmed that the scientific evidence on global warming is the frame of reference for all climate-protection strategies. (2) "After almost 20 years of lofty announcements and sustainability kitsch, the meeting made it brutally clear how little the respective sovereign states are willing to contribute to the well-being of humankind."

  Many bilateral and multilateral activities will unfold when the various parties recover from the self-afflicted shock. "Bonn will be a crucial test-bed for avenues beyond the Copenhagen quagmire." A convincing international, legally binding and effective climate agreement must be put in place that is considered "tolerable, if not fair, by practically everybody." There is still time to replace the climate-policy-as-usual agony with such a vision. The problem in Copenhagen was primarily the US and China, not the many small countries. "If the two were willing to cooperate on climate protection, then the UN system would also work fine."

- Roger Pielke Jr., of the University of Colorado, Boulder, felt that there is no way the world will coordinate efforts to stabilize greenhouse gas emissions through binding targets and timetables for reducing emissions. "Yet many in the climate debate seem ready to put the Copenhagen experience out of their minds and gear up for doing it all over again in Mexico City. Insane!"

  The way to achieve any climate change goals is not through global temperature targets but through technology, innovation and economics. There must be a direct focus on decarbonization of the global economy through improved energy efficiency, expanding low-carbon energy supply not through treaties but through processes of innovation "implemented over many, many decades in a frustrating and incremental process." [31]

  These goals are largely compatible with policies focused on improving energy security and expanding energy access for the 1.5 billion people without electricity. "It would be interesting to see countries negotiating an upstream carbon tax and a mechanism for its proceeds to support decarbonization, energy security and enhanced access to electricity. Such negotiations would still be very complicated and political."

[31] Refer Hoegh-Guldberg (2010d) on technology, built around W. Brian Arthur's treatise on the nature of technology (Arthur 2009). Arthur describes the innovative process as time-consuming and complex, but essential for continued progress. Pielke evidently agrees.

- Bill McKibben of 350.org noted that 112 nations – almost 60% of UNFCCC signatories – endorsed a 350 ppm target for atmospheric CO_2 in Copenhagen. But he said they were the "wrong" 60% made up by poor and vulnerable countries, and China and the US were not among them. "But in some sense, the US and China, having broken the UN process, also bought it. That is, success and failure are increasingly on their shoulders. We in civil society need to figure out how to highlight that." Success or failure is increasingly dependent on these two countries.

All six commentators would agree with Schellnhuber that the science must be the frame of reference for all climate policy formation – a view nearly universally held.[32] From this crucial consensus, three main viewpoints emerged in Copenhagen:

1. There is a growing realization, following the global financial crisis and COP-15, that fewer people are currently willing to invest substantially in climate change mitigation, and that government policy reflects this. This view was expressed most strongly by Victor and Schellnhuber.

2. The United States and China are the catalysts. Agreement between these will determine whether an effective and legally binding agreement covering all countries can be put in place (Lash, Victor, Schellnhuber, McKibben).

   Whatever politically motivated display they exhibited at COP-15, it is noteworthy that both countries were among the five that put the Copenhagen Accord together, practically in the last hours of the conference. President Obama in his closing statement said nations had made a "meaningful and unprecedented breakthrough" but must continue to seek a legally binding agreement.

   Other sources show that contrary to some still popular perceptions, China is making a massive effort to introduce greener technologies associated with huge business opportunities, so market-driven forces may begin to exert stronger positive influences on climate policy. The *China Greentech Report* (Crachilov et al. 2009) provides a thorough analysis of what may happen across a wide range of Chinese sectors.[33] The preface of the report describes it as an open-source, commercial collaboration of leading green technology companies, entrepreneurs, investors, NGOs and policy advisers.

3. Climate policy must refocus on direct approaches to decarbonization through technological change, innovative processes, energy efficiency, and incentives (Hulme, Pielke). The case for an alternative approach to climate change policy will now be discussed. It may also provide a path past the political unwillingness to deal with climate change through general but punitive devices such as emissions trading schemes.

A "PRICE COLLAR" TO REDUCE RISK

The volatility and uncertainty of the environment within which countries have to make their commitments to reduce greenhouse gas emissions, is a major macroeconomic concern. The

[32] Chapter 1 of Clive Hamilton's pessimistic book on the future of our species (Hamilton 2010) is titled "No escaping the science." All else flows from that. See further Hoegh-Guldberg (2010d).

[33] Summarized in Hoegh-Guldberg (2010d).

magnitude of the problem is amply demonstrated by the global economic crisis. Additional uncertainties include unexpected economic growth, technological breakthroughs, price trends for renewable energy, and political instability. It is very difficult, in this environment, to establish price targets for greenhouse gas emissions that are demonstrably comparable across countries.

The Brookings Institution's policy director of climate and energy economics, Adele Morris, has advocated a "price collar" to ensure comparable efforts by nations based on comparable price signals for carbon (McKibbin, Morris and Wilcoxen 2009). The price collar sets starting floor price and price ceilings, which then rise annually for a ton of carbon dioxide-equivalent emissions at a predetermined rate plus adjustment for inflation, over the course of the agreement. Morris and her colleagues see the price collar as an effective and economically viable way to move international climate negotiations forward, especially for developing countries where the future uncertainties and the cost are greatest. Focusing exclusively on reductions of historical levels of emissions has greatly hampered climate negotiations. Introducing a sensibly defined price collar would provide a way of easing countries into the agreement by reducing the risk and uncertainty, and offering a transparent and verifiable assurance that countries put in a comparable effort.

A price collar has been adopted in the climate legislation being proposed by Senator Kerry and his colleagues, as reported in the next section.

SHOULD CLIMATE POLICY CHANGE RADICALLY?

An argument in favor of an alternative approach to "getting climate policy back on course" was put forward in a paper under the auspices of the London School of Economics and the University of Oxford (Prins et al. 2009). Co-authors include Mike Hulme and Roger Pielke, whose comments were summarized in the previous section. The paper was published months before COP-15 but reflects the difficulties caused by the economic crisis. Another paper has since been published following COP-15, reported at the end of this section (Prins et al. 2010).

Prins et al (2009) demonstrates that there has been no acceleration in the rate at which the main economies, the European Union, United States, Japan, and China, have "decarbonized" in terms of *carbon intensity* – tons CO_2 produced per thousand dollars of GDP adjusted for inflation. Indeed, the data show China "*re*carbonizing" between 2002 and 2006, the last year included.

The paper is based on the so-called Kaya identity which elegantly ascribes changes in CO_2 emissions to just one of four factors: population, wealth (GDP per person), energy intensity (energy used per unit of GDP), and carbon intensity (CO_2 produced per unit of GDP). Bill Gates (2010) in a public presentation commented on each element of the identity (Emissions = P × S × E × C) in the following terms:

- *P = population* is expected to increase from just under 7 billion in 2010 to just over 9 billion by 2050 (it then starts declining according to the main global scenarios A1 and B1). Some but not much control can be exerted on this element over the next few decades.

- *S = services* (Gates's terminology; the proxy is GDP at constant prices per person) is also largely a given in planning terms, and will continue to increase. The developing world, led by China and India, will insist on benefiting from increasing wealth.
- *E = energy intensity* is falling, not rising, in contrast to P and S. In some economic sectors, energy efficiency may increase by up to 90%. While the potential varies widely from sector to sector, considerable overall improvement is possible according to Gates. Energy efficiency is one of three main categories of technological change (Hoegh-Guldberg 2010d). The others are new energy technologies and land and coastal management.
- *C = carbon intensity* is the key factor. It will not fall through continued conventional use of coal and natural gas, but through what Gates calls "energy miracles" of which he selects five for further consideration: carbon capture and storage, nuclear energy, wind power, solar photovoltaic power, and solar thermal power. The relative merits of these choices in Gates's view are discussed in the section on nuclear fission in Hoegh-Guldberg (2010d).

The Kaya identity is named after Professor Yoichi Kaya of Keio University, Tokyo, Director-General of Japan's Research Institute of Innovative Technology for the Earth. Prins et al. (2009) credited Kaya with the insight that the four components are the *only* macro-scale policy levers that affect CO_2 emissions.[34]

The main message of the paper is (Prins et al. 2009, p 3): "If countries really aspire to cut emissions, we suggest that the motor of an effective mechanism is a direct approach to the decarbonization of the global energy system, rather than an indirect approach via manipulation of the economy. The logic behind this direct approach is explained by the Kaya Identity."[35]

Each of the four factors in the identity is amenable to the action of a particular lever and each lever prescribes a particular approach to policy. "In the case of population, the lever is population management. In the case of wealth, the lever is to reduce the size of the

[34] The Kaya identity was explored by Waggoner and Ausubel (2002), who found it related generally to dematerialization, not just decarbonization, though CO_2 reduction was part of the examples given. The authors noted the connection between the Kaya identity and the "IPAT identity" developed in 1972 by Barry Commoner, Paul Ehrlich, and the future science and technology adviser to President Obama, John Holdren (references in Waggoner and Ausubel 2002). IPAT defined the environmental impact (I) of population (P), affluence (A), and technology (T). Of these, only population has retained its original meaning, while impact, affluence (which Gates called S) and technology (E×C in Kaya) have all changed definitions and dimensions. Technology, for instance, has been cast as both villain and hero and has been a mere residual left over – a treatment which goes straight against the concept of technology demonstrated in Hoegh-Guldberg (2010d). Hamilton (2010, p 46) analyzes IPAT, finding it places an almost impossible burden on the role of technology. Looking at energy and carbon intensity individually still indicates a formidable task, but at least these elements can receive separate focus through the Kaya identity.

[35] What seems a portent happened in April 2010 when the investment newsletter, *The Green Chip Review*, finally – almost a year after Prins and his colleagues published their paper – acknowledged the nail in the coffin of cap-and-trade, after having avidly supported it previously. It blamed the change on fraudulent use of existing schemes in Europe and Asia and "highly bureaucratic language and complicated rules." Carbon dioxide emissions should be priced because the atmosphere is not a public good, but a straight carbon tax would benefit the competitive position of clean-energy companies. "Instead of paying for carbon permits, a tax would force utilities and manufacturing businesses to adopt more sustainable practices." (Hodge 2010)

economy. In the case of energy intensity, the lever is to increase energy efficiency. And for carbon intensity, a switch to energy sources that generate fewer emissions is the primary lever." (p 4)

As Gates (2010) shows, population management and reducing the economy are politically unrealistic, which leaves policies to improve energy efficiency and switching to renewable energy. [36] Prins et al. (2009) agree and "for reasons of political feasibility as well as of efficiency" define what they call the Kaya Direct Approach "focusing on energy intensity and carbon intensity and not on population and wealth." (p 10)

The paper concentrates on the prospects for decarbonization as a focus of those factors that articulate with greenhouse gas emissions and economic growth, rather than "an indirect and perhaps non-existent chain of causations." (p 4)

The authors conclude (pp 14-15):

1. The Kaya Direct Approach offers the best way forward for decarbonization, and humanity will perhaps inevitably pursue this approach in view of the political realities of energy and climate policies around the world.
2. This is consistent with incorporating new science into policy-making because it preserves an ability to adjust to new knowledge and policy performance. Climate policy must be robust to uncertainties that can break in any direction. The approach improves efficiency and reduces costs, which reliably translates into greater profitability.
3. The momentum of climate policy was brutally halted by the recession, but this offers a chance of replacing dogmatism with pragmatism – taking a direct approach to decarbonization rather than setting targets bound to be vigorously opposed by voters and elected politicians. The focus should switch to actions that have worked in the past and are politically feasible, away from the current approach which has not worked in the past and has not yet proven to be politically feasible.

Reviewing a batch of new "post-Copenhagen" books for *Nature*, Pielke (2010) finds climate change at a crossroads, and once again asserts his conviction that continuing down the path followed to date will not work.

"Climate science has become deeply politicized and climate politics is in gridlock. Climate change is at risk of becoming an issue of cultural politics, similar to the evolution debate in the United States and elsewhere. If the climate-policy debate is to continue as it has, we should expect more of the same.

An alternative way forward would start by admitting the limitations of science in compelling political agreements, and by admitting that we do not know how to complete the challenge of decarbonizing the global economy. There may be greater prospects for political consensus if scientists acknowledge their humility rather than asserting their authority. Incremental approaches to climate mitigation that can be modified by experience offer a chance that

[36] There may be marginal efforts to influence P and S, like encouraging the reduction of birth rates in countries lagging behind the general international trend, and even placing subtle restrictions on the growth rates of rich countries, but the total effect of such measures over the coming few decades is unlikely to have major potential.

realistic and democratically grounded actions might rise to a challenge that will be with us for decades to come." (p 353)

Prins and some of his co-authors of the 2009 paper including Mike Hulme and Roger Pielke have since taken the message further (Prins et al. 2010, dubbed "The Hartwell Paper"). "The UNFCCC/Kyoto model of climate policy cannot continue because it crashed in late 2009. .. The crash of 2009 presents an immense opportunity to set climate policy free to fly at last." (p 6) The failure of the Copenhagen conference in December to secure a binding agreement (coupled with the critique of IPCC's authority which emerged in early 2010 over "mistakes") therefore supported the conclusions reached in the 2009 paper of Prins and his co-authors.

Concerned that "the current framing and climate change and climate policy has 'boxed us in'" (p 8), the new paper advocates a radical reframing of the approach, accepting that decarbonization will only be achieved successfully as a benefit contingent upon other goals which are "politically attractive", "politically inclusive", and "relentlessly pragmatic." (p 11)

The paper advocates that the organizing principle of the effort to combat climate change should be "the raising up of human dignity [37] via three overarching objectives: ensuring energy access for all; ensuring that we develop in a manner that does not undermine the essential functioning of the Earth system; ensuring that our societies are adequately equipped to withstand the risks and dangers that come from all the vagaries of climate, whatever their cause may be." (p 5)

Above all, the paper "emphasizes the primacy of accelerating decarbonization of energy supply. This calls for very substantially increased investment in innovation in non-carbon energy sources in order to diversify energy supply technologies. The ultimate goal of doing this is to develop non-carbon energy supplies at unsubsidized costs less than those using fossil fuels. The Hartwell Paper advocates funding this work by low .. dedicated carbon taxes."

The technological background paper (Hoegh-Guldberg 2010d) refers to the futility of single solutions to climate change and in effect advocates multiple approaches across the range of renewables, energy efficiency, and the maintenance and preservation of carbon sinks – as well as the pointing to the importance of diffusing new technologies and genuine innovation to a wide range of nations.

IMPLICATIONS

As Prins et al. (2010) emphasize, the outcome in Copenhagen indicated that the approach taken to date needs to be considerably or even radically modified. A successor agreement to the Kyoto Protocol based solely on the top-down UNFCCC policy process is unlikely to succeed unless it is strongly supported by the domestic policies of the major industrialized and developing economies. The failure of the Obama administration to secure the passage

[37] Currently, all the framings and agendas are mobilized to advance the one core goal of decarbonizing the energy system via the UNFCCC/Kyoto process. (p 9) Prins et al. (2010) that this principle of attacking "sinfulness" hasn't worked; but a positive approach should work better.

of a cap-and-trade bill through the Senate in 2009 weakened the American influence on the Copenhagen Accord at a time when strong leadership was called for.

Efforts to put a United States climate bill through the Senate were revived in November 2009 when Senators John Kerry (D-MA), Joe Lieberman I-CT), and Lindsey Graham (R-S.C.) got together to explore bipartisan support. In March 2010, Senate majority leader Harry Reid urged Senator Kerry and his colleagues to produce a proposal with all possible speed. An eight-page outline was discussed with senators and leading industry associations on March 18, reported to call for greenhouse gas curbs across multiple sectors to achieve a 17% reduction below 2005 levels by 2020 and an 80% reduction by 2050.[38] The trio had scrapped a wide-ranging cap-and-trade system in favor of one covering the 40% of emissions associated with electric utilities which would provide the main revenue for the broader legislation. Subsequently, Senator Graham withdrew his support, leaving the initiative in the hands of Senators Kerry and Lieberman.

The draft dealt in turn with refining, America's farmers, consumer refunds, clean energy innovation, coal, natural gas, nuclear, and energy independence. The proposal was also reported to introduce a "hard price collar" limiting greenhouse gas emissions to between $10 and $30 per ton, tagged to inflation and with an increase at a fixed rate for future years. This was the exact concept promoted by Adele Morris and her colleagues to reduce uncertainty and risk (McKibbin et al. 2009).

President Obama expressed strong support for a bipartisan effort to establish clean energy incentives that will create jobs and reduce America's dependence on foreign oil. The best way to drive a transition to a clean-energy economy was to give business the predictability and continuity it needs to make investments.

As this report was nearing its conclusion in July 2010, the outlook for passing a climate bill through the Senate before the mid-term elections in November became highly uncertain, but a fourth attempt was being prepared after three failures in 2009. Senators Kerry and Lieberman were reworking their compromise climate bill, concentrating on power plants and removing provisions to phase in other sectors at a later date. Senate majority leader Harry Reid was working on a climate and energy draft bill that might include the power plant caps from the Kerry-Lieberman bill within a wider alternative energy plan. Reid's initiative looked the best chance of making headway in the Senate, but would be constricting the chances of contentious legislation getting through.

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[38] On March 31, 2010, President Obama announced a decision to open up oil and gas exploration in three areas: "We're announcing the expansion of offshore oil and gas exploration but in ways that balance the need to harness domestic energy resources and the need to protect America's natural resources. .. This announcement is part of a broader strategy that will move us from an economy that runs on fossil fuels and foreign oil to one that relies more on homegrown fuels and clean energy. And the only way this transition will succeed is if it strengthens our economy in the short term and long term." The plan would allow drilling along the Atlantic coastline, the eastern Gulf of Mexico (125 miles off Florida's coast), and the north coast of Alaska. It would end a longstanding moratorium on exploration from the northern tip of Delaware to the central coast of Florida, covering 167 million acres of ocean. The Pacific coast would remain closed to oil and gas exploration.

President Obama's decision was attacked by environmental interests and politicians, including senators from Florida pointing out the risks to the state's economy and environment. He was reported to be hoping to get support from Republicans for a climate change bill in turn for his concession to the oil and gas exploration industry. The Gulf oil spill disaster in May 2010 may also assist in securing support, as suggested in Scenario B1.

In early July, President Obama convened a cross-party group of twenty Senators constituting the main players in the climate legislative debate to urge them to pass climate legislation with a price on carbon emissions. Obama did not prescribe any particular approach (*Carbon Positive* 2010).

By signing onto the Copenhagen Accord in December 2009, the United States accepted the goal of cutting 2005 domestic greenhouse gas emissions by 17% by 2020. This appears to be the one area of consensus on US climate action, although the target fell short of international expectations for a new global climate agreement. Eileen Claussen, president of the Pew Center on Global Climate Change said a cap on utility emissions would result in a 12-14% cut by 2020. "It's not 17, but I think it's not terrible," she said.

However, the estimate assumed that the utility cap-and-trade program would be coupled with other pollution-reduction steps, such as requiring more fuel-efficient heavy trucks and improving building efficiency standards – initiatives that could be folded into a large energy and environment bill. According to Pew, the reductions in utility sector emissions alone in the draft law translated roughly into an economy-wide 7% cut in fossil fuel pollution by 2020 (Cowan 2010).

Whatever will be the final outcome in the USA, a universal cap-and-trade scheme is becoming less likely, which may also reduce the probability of such schemes being introduced in other countries. While the cap has been seen by some as the most efficient way of legislating a total limit on emissions, the scheme at least in the perspective of 2010 no longer appears to be politically feasible. Moving away from a universal cap-and-trade system implies that other financial revenue schemes will take up the slack, including carbon-based taxes. To be politically acceptable, it has been suggested such taxes should be revenue-neutral, offset by tax relief including lower payroll and other distorting taxes.

So climate policy seems likely to become based on a more piecemeal approach, with cap-and-trade schemes limited to public utilities and a variety of other schemes being phased in for other industries. This would be generally in line with the idea of tackling greenhouse gas emissions through a range of direct approaches to the two parts of the Kaya identity that can be most effectively influenced: energy efficiency and carbon emissions per unit of GDP.

THE KEY ISSUES REMAIN LARGE-SCALE

- The primary issue is unchanged: the scientific evidence is clear that tackling climate change is becoming increasingly urgent. Despite what happens at international conferences and what is revealed through domestic polls and government policies, the idea that climate change doesn't exist or is going away is erroneous and damaging.
- Climatologists and other scientists urgently need to sell their message more convincingly to all stakeholders, encouraging a genuine dialogue where the scientists listen as well as lecture. As the previous point makes clear, the urgency of introducing effective climate change policies nationally and internationally has not gone away.
- Science and economics need to work together to understand how to ensure climate control. The scientific evidence was the subject of Hoegh-Guldberg (2010a). The present background paper is an extended argument for updating the state of economic thought

on a continuing basis. Science is the catalyst but economics is the lubricant which helps change happen and be accepted. Just as science can get its arguments and findings wrong, the economic lubricant can be more or less efficient. Both need to be as competent and comprehensible as possible at all times.

- The outcome in Copenhagen, influenced by the global economic crisis, has damaged the top-down approach to securing binding overall emissions targets. However, the targets remain highly relevant. The Copenhagen Accord fortunately recognized that the increase in global temperature must be limited to $2^{O}C$ above pre-industrial levels.
- While Sino-American cooperation may have been a dominant issue in Copenhagen, the thread running through the conference was the need to support developing countries in their climate change policies. The pledge to distribute funds through a green climate fund is a promising beginning, but is it enough and will it be rigorously followed up?
- The dynamics of international climate policy may never be the same again if China's "greentech" initiative takes off as dramatically as anticipated. The impact may be disruptive, or it may prove highly constructive and provide a powerful lever for future international negotiations. There are further questions: will China be unique in this respect, or will there be international ripple effects? Or will there be independent moves in other countries or regions? Where is the next economic miracle likely to be?
- National policy evidenced by current US efforts is not favoring a comprehensive cap-and-trade regime, but it may back a partial one based on the electrical utility sector. The likely approach now is to treat each industry sector in its own context, which is in line with the decarbonization approach directed toward the fourth element of the Kaya identity on how to minimize carbon intensities. This principle seems meritorious.
- Breaking the policy measures up into smaller parts with a flexible set of priorities encourages massive lobbying. It should be possible, however, to put some boundaries on this through clear policy directions and guidelines across the range of technological options – in any case, the lobbying was also massive prior to the financial crisis. Some possible options are being explored, for example through the US Department of Energy's ARPA-E program described in Hoegh-Guldberg (2010d).

THE ECONOMIC PARADIGM UNDER ALTERNATIVE SCENARIOS

This background paper has drawn on a wide number of sources to help identify how economics and economic policies may develop in future:

1. The renewed recognition of "irrational" behavior patterns under the heading of "animal spirits"
2. The recognition of climate change as the cause of the largest market failure ever
3. The influence of complexity theory and general influences from other social and physical sciences
4. Influences since the onset of the global economic crisis.

The economic paradigm differs between the four scenarios, as shown in Chapter 6 of the main report. Without going into detail, the currently prevailing economic thinking is likely to

be most prominent in the global economic growth-oriented A1 scenario, whereas the environmentally attuned B1 gives more space to the economics of climate change and the collaboration between economists and scientists. The paradigm is different again in the regionalized scenarios, A2 and B2, partly because of the projections of continued population growth in these scenarios, though the worlds they depict are poles apart.

ADDENDUM 1: ANIMAL SPIRITS IN THE *GENERAL THEORY*

Chapter 12 of Keynes' *General Theory* is titled *The state of long-term expectation* (pp 147-164 in the original 1936 version). The chapter reads almost as freshly today as it did when written, and brings the "animal spirits" which he introduced towards the end, into focus. It is all about investment, being part of Book 4 of the *General Theory*, which he called *The inducement to invest*.

The chapter has eight parts, from I to VIII (VII on animal spirits is quoted in full).

I. The previous chapter established that "the scale of investment depends on the relation between the rate of interest and the schedule of the marginal efficiency of capital corresponding to different scales of current investment, whilst the marginal efficiency of capital depends on the relation between the supply price of a capital-asset and its prospective yield." (P 147)

   The state of psychological expectation covers the state of long-term expectation (as distinct from the short-term expectation where a producer estimates what he will get for a product if produced today on his existing plant).

II. The state of long-term expectations on which our expectations are based does not depend solely on the most probable forecast we can make. It also depends on the *confidence* with which we can make this forecast – how we rate the likelihood of our best forecast turning out quite wrong. If we expect large changes but are very uncertain as to what precise form these changes will take, then our confidence will be weak.

   The *state of confidence* is very important to business people but economists have not analyzed it carefully. "In particular, it has not been made clear that its relevance to economic problems comes in through its important influence on the schedule of the marginal efficiency of capital. There are not two separate factors affecting the rate of investment, namely, the schedule of the marginal efficiency of capital and the state of confidence. The state of confidence is relevant because it is one of the major factors determining the former, which is the same thing as the investment demand schedule." (p 149)

   "There is ... not much to be said about the state of confidence *a priori.* Our conclusions must mainly depend upon the actual observation of markets and business psychology. This is the reason why the ensuing digression is on a different level of abstraction from most of this book." (p 149)

   To bring the point home, the discussion of the state of confidence that follows assumes that there are no changes in interest rates.

III. We know little about how to estimate the yield of a railway, copper mine or textile factory 10 years hence, or even five years hence. And with the separation between ownership and management epitomized by the stock exchange "a new factor of great importance has entered in, which sometimes facilitates investment but sometimes adds greatly to the instability of the system." (pp150-151) " … "Thus

certain classes of investment are governed by the average expectation of those who deal on the Stock Exchange as revealed in the price of shares, rather than by the genuine expectations of the professional entrepreneur." (p 151)

IV. In practice, we rely on a *convention*, assuming that the existing state of affairs will continue indefinitely, except when we have reason to expect a change. "We are assuming, in effect, that the existing market valuation, however arrived at, is uniquely *correct* in relation to our existing knowledge of the facts which will influence the yield of the investment, and that it will only change in proportion to changes in that knowledge … ." (p 152)

V. Weak points of the convention:
   a. The element of real knowledge in the valuation of investments by those who own them or contemplate purchasing them has seriously declined as a result of the separation of ownership and management due to the stock market.
   b. "Day-to-day fluctuations in the profits of existing investments, which are obviously of an ephemeral and non-significant character, tend to have an altogether excessive, and even an absurd, influence on the market." (pp 153-154)
   c. "A conventional valuation which is established as the outcome of the mass psychology of a large number of ignorant individuals is liable to change violently as the result of a sudden fluctuation of opinion due to factors which do not make much difference to the prospective yield … ." (p 154)
   d. The attention of expert professionals who have better judgment and knowledge is elsewhere. They are concerned not with making superior long-term forecasts but with forecasting changes in the conventional basis of valuation a short time ahead of the general public. They are concerned with market valuation based on mass psychology, three months or a year ahead.
   e. The other facet of the *state of confidence* is the confidence of the lending institutions towards those who seek to borrow from them, sometimes described as the *state of credit*. Either the state of confidence or the state of credit can cause a collapse but recovery requires the revival of both. "For whilst the weakening of credit is sufficient to bring about a collapse, its strengthening, though a necessary condition of recovery, is not a sufficient condition." (p 158)

VI. *Speculation* is the activity of forecasting the psychology of the market; *enterprise* is the activity of forecasting the yield of assets over their whole life. While speculation does not always predominate over enterprise, the influence of speculation on Wall Street is enormous. "Even outside the field of finance, Americans are apt to be unduly interested in discovering what average opinion believes average opinion to be; and this national weakness finds its nemesis in the stock market" (p 159). As distinct from the British, he buys equity for capital appreciation rather than "for profit". "It is usually agreed that casinos should, in the public interest, be inaccessible and expensive. And perhaps the same is true of Stock Exchanges." (p 159)

VII. The animal spirit chapter is quoted in full (pp 161-163):

"Even apart from the instability due to speculation, there is the instability due to the characteristic of human nature that a large proportion of our positive activities depend on spontaneous optimism rather than on a mathematical expectation, whether moral or hedonistic or economic. Most, probably, of our decisions to do something positive, the full consequences of which will be drawn our over many days to come, can only be taken as a result of animal spirits – of a spontaneous urge to action rather than inaction, and not as a result of a weighted average of quantitative benefits multiplied by quantitative probabilities. Enterprise only pretends to itself to be mainly actuated by the statements in its own prospectus, however candid and sincere. Only a little more than an expedition to the South Pole, it is based on an exact calculation of benefits to come. Thus if the animal spirits are dimmed and the spontaneous optimism falters, leaving us to depend on nothing but a mathematical expectation, enterprise will fade and die; – though fears of loss may have a basis no more reasonable than hopes of profit had before.

It is safe to say that enterprise which depends on hopes stretching into the future benefits the community as a whole. But individual initiative will only be adequate when reasonable calculation is supplemented and supported by animal spirits, so that the thought of ultimate loss which often overtakes pioneers, as experience undoubtedly tells us and them, is put aside as a healthy man puts aside the expectation of death.

This means, unfortunately, not only that slumps and depressions are exaggerated in degree, but that economic prosperity is excessively dependent on a political and social atmosphere which is congenial to the average business man. If the fear of a Labour Government or a New Deal depresses enterprise, this need not be the result either of a reasonable calculation or of a plot with political intent; – it is the mere consequence of upsetting the delicate balance of spontaneous optimism. In estimating the prospects of investment, we must have regard, therefore, to the nerves and hysteria and even the digestions and reactions to the weather of those upon whose spontaneous activity it largely depends.

We should not conclude from this that everything depends on waves of irrational psychology. On the contrary, the state of long-term expectation is often steady, and, even when it is not, the other factors exert their compensating effects. We are merely reminding ourselves that human decisions affecting the future, whether personal or political or economic, cannot depend on strict mathematical expectation, since the basis for making such calculations does not exist; and that it is our innate urge to activity which makes the wheels go round, our rational selves choosing between the alternatives as best we are able, calculating where we can, but often falling back for our motive on whim or sentiment or chance."

VIII. Certain factors mitigate in practice about our ignorance of the future. Due to compound interest combined with the likelihood of obsolescence, it may be legitimate that the prospective yield is dominated by returns occurring in a comparatively near future.

In buildings, the risk can be frequently transferred from the investor to the occupier, or shared between them based on long-term contracts where the occupier buys continuity and security of tenure.

In public utilities, much prospective yield is practically guaranteed by monopoly privilege (rates set to secure a stipulated margin).

A growing class of investments by public enterprises provide social advantages from the investment (whatever the community yield).

In conclusion:

"For my own part I am now somewhat sceptical of the success of a merely monetary policy directed towards influencing the rate of interest. I expect to see the State, which is in a position to calculate the marginal efficiency of capital-goods on long views and on the basis of the general social advantage, taking an even greater responsibility for directly organising investment; since it seems likely that the fluctuations in the market estimation of the marginal efficiency of different types of capital, calculated on the principles I have described above, will be too great to be offset by any practicable changes in the rate of interest." (p 164)

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John Maynard Keynes, *The General Theory of Employment, Interest and Money,* Chapter 12 ("The state of long-term expectation"). Macmillan & Co Ltd, London, 1936.

ADDENDUM 2: SCHUMPETER ON ECONOMIC DEVELOPMENT

From *Capital, Socialism and Democracy* (1942), pp 82-84:

"The essential point to grasp is that in dealing with capitalism we are dealing with an evolutionary process. It may seem strange that anyone can fail to see so obvious a fact which moreover was long ago emphasized by Karl Marx. Yet that fragmentary analysis which yields the bulk of our propositions about the functioning of modern capitalism persistently neglects it. Let us restate the point and see how it bears upon our problem.

Capitalism, then, is by nature a form or method of economic change and not only never is but never can be stationary. And this evolutionary character of the capitalist process is not merely due to the fact that economic life goes on in a social and natural environment. … The fundamental impulse that sets and keeps the capitalist engine in motion comes from the new consumers' goods, the new methods of production or transportation, the new markets, the new forms of industrial organization that capitalist enterprise creates.

The contents of the laborer's budget, say from 1760 to 1940, did not simply grow on unchanging lines but they underwent a process of qualitative change. Similarly, the history of the productive apparatus of a typical farm, from the beginnings of the rationalization of crop rotation, plowing and fattening to the mechanized thing of today – linking up with elevators and railroads – is a history of revolutions. So is the history of the productive apparatus of the iron and steel industry from the charcoal furnace to our own type of furnace, or the history of the apparatus of power production from the overshot water wheel to the modern power plant, or the history of transportation from the mail-coach to the airplane. The opening up of new markets, foreign or domestic, and the organizational development from the craft shop and factory to such concerns as U.S. Steel illustrate the same process of industrial mutation – if I may use that biological term – that incessantly revolutionizes the economic structure from within, incessantly destroying the old one, incessantly creating a new one. This process of Creative Destruction is the essential fact about capitalism. It is what capitalism consists in and what every capitalist concern has got to live in. This fact bears upon our problem in two ways.

First, since we are dealing with a process whose every element takes considerable time in revealing its true features and ultimate effects; we must judge its performance over time, as it unfolds through decades or centuries. A system – any system, economic or other – that at every given point of time fully utilizes its possibilities to the best advantage may yet in the long run be inferior to a system that does so at no given point of time, because the latter's failure to do so may be a condition for the level or speed of long-run performance.

Second, since we are dealing with an organic process, analysis of what happens in any particular part of it – say, in an individual concern or industry – may indeed clarify details of mechanism but is inconclusive beyond that. Every piece of business strategy acquires its true significance only against the background of that process and within the situation created by it. It must be seen in its role in the perennial gale of creative destruction; it cannot be understood irrespective of it or, in fact, on the hypothesis that there is a perennial lull."

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